The Effects Of Added Transportation Capacity

Click HERE for graphic.

Travel Model Improvement Program

The Department of Transportation, in cooperation with the Environmental Protection Agency and the Department of Energy, has embarked on a research program to respond to the requirements of the Clean Air Act Amendments of 1990 and the Intermodal Surface Transportation Efficiency Act of 1991. This program addresses the linkage of transportation to air quality, energy, economic growth, land use and the overall quality of life. The program addresses both analytic tools and the integration of these tools into the planning process to better support decision makers. The program has the following objectives:

1. To increase the ability of existing travel forecasting procedures to respond to emerging issues including; environmental concerns, growth management, and lifestyle along with traditional transportation issues,

2. To redesign the travel forecasting process to reflect changes in behavior, to respond to greater information needs placed on the forecasting process and to take advantage of changes in data collection technology, and

3. To integrate the forecasting techniques into the decision making process, providing better understanding of the effects of transportation improvements and allowing decision makers in state governments, local governments, transit operators, metropolitan planning organizations and environmental agencies the capability of making improved transportation decisions.

This program was funded through the Travel Model Improvement Program.

Further information about the Travel Model Improvement Program may be obtained by writing to:

Planning Support Branch (HEP-22)

Federal Highway Administration
U.S. Department of Transportation
400 Seventh Street, SW
Washington, D.C. 20590

The Effects of Added Transportation Capacity

Conference Proceedings
December 16 and 17, 1991

Prepared by

Gordon A. Shunk
Texas Transportation Institute
1600 East Lamar Boulevard, Suite 120
Arlington, Texas

Funded by

U.S. Department of Transportation
Federal Highway Administration
Federal Transit Administration
Office of the Secretary

U. S. Environmental Protection Agency

Distributed in Cooperation with

Technology Sharing Program
Research and Special Programs Administration
U.S. Department of Transportation
Washington, D.C. 20590

DOT-T-94-12

Contents

Day One: Describing the Problem

David, Chief of the Programming Branch of the San Francisco Office of the Environmental Protection Agency, opened the conference. He noted that one of the EPA's main interests in participating in a conference that dealt with the impacts of added transportation capacity was that frequently the regional offices want to consider the potential growth inducing impact of proposed highway projects. Federal and state agencies often disagree on whether or not increased capacity leads to less congestion and less air pollution. This disagreement, Calkins stated, has been going on for over 10 years; but there was little in the way of unbiased, extensive research to substantiate either claim. For this reason, the EPA is interested in pursuing a multi-agency, multi-year study that will address this issue.

Calkins outlined several benefits that should evolve from this discussion. Overall, developing information that can be used to improve the p g and decision-making process in air quality and transportation projects will reduce conflicts. By being more knowledgeable about the actual effect of added capacity, transportation and air quality plans can be coordinated more effectively. Modeling procedures can also be improved as more and better information on travel behavior is developed. The conference will assist in developing the state implementation plan control strategies of the 1990 Clean Air Act Amendments (CAAA), as well as support measures of the Intermodal Surface Transportation Efficiency Act (ISTEA). Other benefits include more cost-effective air quality improvement strategies and better justifications and alternatives to the public for transportation control measures. There should also be a focus on access, not just on mobility and ease of travel issues. Access issues include providing transportation facilities for the elderly, the poor, the young, and the handicapped.

Calkins stressed the importance of study design and the need to include all interested parties at the outset of the study, including Metropolitan Planning Organizations (MPOs), federal agencies, local air quality agencies, environmental groups, and land use planners and developers. A long-term funding commitment from all of these organizations will be necessary for a successful study.

In conclusion, Calkins stated that the conference was an opportunity to improve the quality of life, as health is the basis for the CAAA and air quality regulations. By learning about how travel growth patterns interact with existing infrastructure and other factors, transportation and land use systems can be designed that are efficient, clean, and provide good access to services, jobs, and recreation.

Kevin Heanue, Director, Office of Planning of the Federal Highway Administration, felt that the conference was a step in seeking a broader audience in laying out a research agenda on the issue of the impacts of added transportation capacity. By identifying major and minor topics to address, better guidance can be provided to those MPOs that are involved in air quality analysis and state implementation plan updates.

Heanue stressed the importance of eliminating the use of environmental specialists only at a project's end. By bringing environmental resources into the project at the outset and integrating those efforts with the planning efforts, the relationships between air quality, travel, and development will be better understood. As an example of an effort to promote this integration, Heanue said, the FHWA merged the offices of Environment and Planning in to one unit several years ago. The FHWA also has a policy to foster strong linkages with the environmental community. This is reinforced in the CAAA and ISTEA legislation.

The responsibilities of the are changing, Heanue said. There is a broader analytical framework within which there are more choices than the traditional highway option; there are highway transit options, for example. The MPOs are in a position to make the initial recommendation whether transportation investments are highway or transit.

Heanue said that a need exists for increased environmental research and more accuracy and sensitivity in the present models. By asking the questions of whether or not latent demand or induced traffic is a valid concept, and how new capacity affects new travel behavior, there will be new feedback for the modeling process. He then stated the need for simpler modeling mechanisms, as opposed to the modeling processes of the early 1960's. What is needed are logical and practical models that recognize the accuracy of the base data and target objective. Heanue then concluded his remarks by suggesting that there were two agendas to approach at the conference. One was the research agenda, where to invest the research money for the best results, and the other was the practice. What can be learned from the study that would benefit the 280 MPO transportation planners who would be faced with the implementation and technical responsibilities of the CAAA and ISTEA?

Edward Weiner, Senior Policy Analyst with the Office of the Secretary of Transportation, served as moderator for the first session and offered a conclusion to the introductory remarks. He noted that it was encouraging to see the cooperation between the EPA and the Transportation Department in the effort to implement the various provisions of the CAAA. He also reiterated the general questions that the conference would be trying to address. First, what is known about the relationship between the various phenomena involved and the effect of added capacity and induced travel? Second, what are the key variables involved? And, third, can a good understanding of how to measure the process be gained in order to design impact or measurement studies that will successfully measure this phenomena?

Transportation Investment and Metropolitan Economic Development: A Reconnaissance of Research Availability and Requirements

Alan E. Pisarski

This presentation outlined available research and literature for a research effort on land use impacts of major rail and related investments. The presentation consisted of three main topics: a review of the findings of a research and literature review, a discussion of ways to expand on the review, and questions that will be beneficial to the intent of the conference.

One of the major findings of the literature review is that the subject of land use impacts is debatable, as there is no common terminology throughout the literature. Material is available in all aspects of transportation research including land use development, economic development, impact analysis, and efficiency studies. The material also extends into other disciplines such as economics, geography, and sociology. Several consistent elements are evident, in spite of the disparity of sources. There is a tendency to focus on the economic effects of investment, most noticeably the employment and construction effects. The economic effects are further divided into direct, indirect, primary, and secondary influences. The older literature focuses more on the traditional logistical models of the coal or steel industries and their relation to transportation, while the newer materials looks at the new economic effects of the service industry. The ability to include the transportation element in the new service-oriented economy is not well developed. Finally, for the most part, the literature centers around major transportation projects, such as San Francisco's Bay Area Rapid Transit (BART) project The emphasis and analysis on these large undertakings has been on generational effects, demand changes, and land use effects. Several problems are evident with the before-and-after impact studies generated from the large projects. Often, these studies were under-funded and never completed; or after long periods of time, the findings are irrelevant, given the changes that occurred.

Over the years, highway analysis shifted from attempts to justify the facility in terms of its development effects to a more conciliatory tone of how to solve development-generated problems, such as congestion and environmental impacts. There currently is a shift back to the economic development argument as more projects such as toll roads are being considered by private developers or public/private cooperatives.

The aviation sector can be studied as an example of economic development. The aviation industry, airports, and air travel capability are a considerable economic engine in any region. Few of the studies reviewed for the presentation focus on the changes in the total economic capability and comparative advantage of a region as a result of changes in local transportation. Aviation can be one of the dramatic economic drivers in a community. This is an area in which to study changes in investments and services and the impacts they have on regional economic climates and developments.

One question that arises from the available research is, is it possible to get beyond a basic assumption that transportation is a necessary, but inconsistent, condition of growth? Additional questions generate from this; for

example, why is there growth adjacent to some transit stations, but not others? What are the positive and negative effects of density? Why are some areas revived by transit development and others are not?

The question of latent demand for local travel is an important element of added capacity impact studies and should be the center-piece of new research topics. How much of travel demand is latent? How do various groups manifest this demand? The tourism industry assumes that there is an enormous quantity of latent demand, and they provide the means and opportunity for demand satisfaction. There is little research available on latent demand; however, the National Personal Transportation Study (NPTS) data being examined for the Federal Highway Administration are a possible source for further study material.

There has been an 18 percent increase in passenger miles traveled from 1983 to 1990. The increase is equally divided between increases in population, average trip length, and per capita trip increases. Is the increase in trip rates and the increase in trips per capita a manifestation of latent demand? If the average trip length increased from 8 to 9 miles, are people better or worse off; and what is gained by the extra mile, greater choice, greater opportunity, lower housing costs, better jobs, or wasted effort? Almost every urban trip culminated in an economic transaction or something of social value, and the shift from latent to actual travel demand should be suppressed.

The increase in travel demand is partially the result of social changes. Also, uses of alternatives to the single occupant automobile has declined, automobile occupancies were down and transit use, walk to work, and telecommuting have all declined. Average travel times have also decreased. The social changes that have had an impact on travel demand are an increase in the vehicle miles traveled by females which has risen 50 percent since 1983 and an increase in single occupancy vehicle use for trips to work by the poor, as examined by the American Housing Survey. All of these changes are part of the democratization of travel which is being encouraged by the low cost of transportation in America.

In conclusion, Mr. Pisarski commented on the feasibility of travel pricing. There is concern that there will be adverse effects on lower income populations if pricing mechanisms are initiated. It will be critical to consider who will be priced out of the transportation system by such measures and the effect this will have on people's lives. These considerations should become a serious part of the research evolving from the conference.

Open Discussion

The discussion opened with a request for Mr. Pisarski to comment on the decrease, rather increase, of average trip length that was occurring in several parts of the country. This decrease is the result of many jobs shifting to the suburbs in contrast to a population shift to the suburbs in search of lower housing costs. In some communities, these two shifts have balanced out the average trip length. One interesting aspect of the NPTS data was that trips of over 30 miles to work have doubled as a percentage of all trips.

The question was asked if work at home, or telecommuting, had declined. Work at home statistics included both metropolitan (professional employment) activities as well as traditional (rural and agricultural) activities. The decline in farming and rural activities accounted for this overall decline.

One participant noted that there were two possible research objectives arising from the presentation: the social objective with transportation demand elements and the economic focus at the state and federal level. The question of how to bring both objectives together was posed. The response was that while it was difficult to coordinate both, it was important to realize how the economic development issues manifest themselves in society. Both economic and social issues can be addressed, for example, in a discussion of possible solutions to the air

pollution problem to get a better sense of the tradeoffs involved. The suppression of travel demand was all too often considered to be a positive action, regardless of the social or economic impact involved. Increased awareness of the social and economic values that are placed on travel by people is necessary.

Effects of Added Transportation Capacity on System Performance

Richard H. Pratt

This presentation was an overview of the effects of added transportation capacity on system performance. These effects are based on several assumptions. First, the added capacity in question is viable if there is sufficient demand for the added facility or service, if the facility or service is sufficiently attractive, and if the facility or service will be used. Second, the added capacity is assumed to be definitely significant such as a new arterial, freeway lane, high occupancy vehicle (HOV) lane addition, or heavy rail transit project.

Eight different ways in which capacity can be achieved are identified:

(1) Strategic highway infrastructure (toll free, mixed traffic)
(2) General mixed traffic highway capacity (toll free)
(3) Ramp metering, other TSM, IVHS
(4) Toll facility capacity
(5) HOV capacity
(6) Transit capacity (on separate ways)
(7) Transit capacity (in mixed traffic)
(8) Multimodal/manageable transportation infrastructure

(1) Strategic highway infrastructure development could be differentiated from generalized highway expansion in that it attempts to provide a missing link in an existing system and, thereby, creates good capacity. By filling in missing links and by removing bottleneck capacity restraints, better system use can occur. Transit operations would also improve because the network on which it operates would be more complete.

(2) The examples given for the generalized addition of mixed traffic capacity included a new highway that parallels an existing highway, a conventional freeway widening project, arterial to freeway conversions, and freeway interchange improvements. Traffic diverted to a new facility improves traffic flow until the system is again overloaded. Improvements to conventional facilities improve, and ultimately, traffic flow is increased. Parallel facilities can provide traffic relief until they, too, become congested. Traffic flow on facilities that provide access to improved major facilities may also increase and become congested as drivers choose to use the major facilities. An HOV lane that exists on a facility where mixed traffic capability is added might experience reduced use because the improved mixed traffic flow reduces the incentive to use the HOV lane. Transit operations on the new facility, however, would be improved, provided these operations were expressed options. Roadway improvements that effect increased traffic by single occupant vehicles have detrimental effects on transit use. Those reductions initiate a downward spiral as transit service is reduced to maintain acceptable operating ratios.

(3) Capacity that is added by actions such as ramp metering or Intelligent Vehicle Highway Systems (IVHS) will also have significant impacts. Ramp metering results in the same effects as generalized highway capacity additions; although it could be managed, for example, by allowing HOV vehicles to bypass the congestion. By backing up traffic, ramp metering often increases the amount of traffic on intersecting streets and neighborhoods and is also problematic at interchanges. In regard to the potential of IVHS, there is concern that if a system were implemented that could

carry three times the present capacity of the conventional highway, what effect would this increase have on the end points of the system? This should be explored further in the IVHS program.

(4) There are several general highway

capacity additions that have toll capabilities. A new toll highway paralleling an existing highway, toll road widening, toll bridges or tunnels, and new toll interchanges are examples. There are several effects to consider as a result of these potential additions, assuming that there is no longer a financial burden and bond holders. Highway traffic flow on the toll facility win be improved and controlled with the toll mechanism, and flow on connecting and intersecting facilities might also be improved. Highway traffic flow on parallel facilities will also improve. Depending on the toll, the opportunity will arise to enhance the HOV facilities, perhaps, by providing free HOV access. The toll road can also potentially become an HOV facility, by letting the HOV riders share in the cost. Free HOV access will also enhance any connecting facilities. Transit operations, too, can be enhanced by toll usage, much like freeways. Transit use at parallel and intersecting facilities will be impacted depending on the toll amount and system design.

(5) Possible examples of added HOV capacity include new HOV facilities, added HOV lanes, HOV contraflow lanes where traffic is imbalanced enough to truly add capacity, and HOV ramps and interchanges. Traffic flow is presumed to improve on the facility, except in cases of friction between HOV and low occupancy vehicles (LOV) on diamond lane situations with crossing traffic flows. The opportunity exists in this situation to manage the traffic flow with changes in HOV occupancy requirements, however. Highway traffic flow on connecting or intersecting facilities will either increase or be mitigated. The opportunity also exists to manage access volume with HOV ramps and interchanges, including mixed traffic access at one location and HOV-only access at another. Traffic flow on parallel facilities will be enhanced by additional HOV capacity, and HOV operation will be enhanced and made more manageable. HOV operations on connecting facilities will also be enhanced. Express transit service will be enhanced, although the impact on service often depends on facility design elements. HOV facility design can have an impact on system performance. One HOV facility in Los Angeles allows the bus to pull directly into the station, then exit with ease, whereas a facility in Houston is designed where the bus has to completely exit the HOV facility, spend approximately five minutes at the station, then reenter the HOV facility. Similarly, a situation exists on interstate 394, in Minneapolis, where the buses, when utilizing the diamond lanes, have to weave across traffic for the station exit with the rest of the traffic, then repeat the competitive process to reenter the facility.

(6) Examples of added transit capacity on separate guide ways include new rail rapid transit and new bus rapid transit, either on busways or on HOV lanes and facilities. Highway traffic flow on parallel facilities has been improved near central business districts (CBDs) and where surface transit volumes are large. Traffic flow is also increased around and approaching transit stations and terminals. An HOV operation parallel to a separate transit way facility often induces a minor reduction in usage. Transit service and capacity is enhanced, unless there are parallel transit operations available. If transit operations intersect,

usage will be enhanced and a major opportunity exists for restructuring to improve circumferential and local service.

(7) Mobility is a key element, as the previous capacity categories and impacts were oriented to those with access to an automobile. By providing transit capacity, mobility is enhanced for that segment of the population without automobile access.

(8) Multimodal transportation infrastructure calls for the provision of multiple modal options and the full integration of those options. Manageable infrastructure will go beyond strategic infrastructure in that it will be designed for maximum efficiency in operation and use through complimenting and enhancing travel demand management. Examples of this of capacity include HOV and transit capacity on separate or concurrent ways within

a corridor and added freeway capacity with HOV and buses. Another example is added transportation capacity introduced in conjunction with transportation system management and travel demand management

There are many expectations of multimodal/manageable transportation capacity. Traffic flow on the facility can be improved and managed as demand increases. There will also be increased traffic flow on connecting or intersecting facilities, but this could be addressed in the facility design. Traffic relief will be seen on parallel facilities, and HOV and transit operations will be improved as a result of the HOV and transit components of the multimodal approach. Mobility will be improved for all sectors.

Open Discussion

One participant suggested that the use of toll facilities implied an obligation to engage in planning and regulatory mechanisms in order for the facility to function properly. The toll mechanism could be one method to control the unused demand and optimize the facility. The question was raised whether public policy issues were being considered with an increased role for tolls and other transportation pricing mechanisms. Mr. Pratt replied that while toll facilities can provide advantages, his intent was to encourage discussion of tolls and their manipulation as an element of transportation management objectives.

There was a brief discussion on what was described as the poly-nucleation of American metropolitan areas. Historically, long distance trips have increased as a result of urban expansion, while the opportunities for short distance trips has decreased. The lack of choice for people to conduct short distance trips by walking or cycling or by making a short bus trip, and a subsequent loss of economic opportunities available to people to meet daily needs through shorter trips, leads to increased automobile dependency. The complexity of the transportation system and the lack of modal diversity leaves people with no freedom to choose how to travel. However, considering the poly-nucleation of cities, a phenomena being experienced in Europe and Japan, as well in the United States, a large city will be comprised of a constellation of small cities. Within this framework the balance can be shifted back to shorter trips within multiple centers, rather than longer trip lengths focusing on a mono-center. The question was asked how the polynucleation concept would mesh with multimodal/manageable transportation capacity in regards to different travel modes accommodating different travel lengths. Mr. Pratt replied by describing a model of a modem multimodal activity center which incorporates HOV system connections and land use designs for pedestrian and bicycle access. This model is very idealized and little has been done to actually implement the concepts; and it was suggested that it be considered as another area for research.

The next question posed was how to determine the extent of the effects of added capacity. Should the extent be measured geographically for an entire urban area or be limited, for example, to a 5-mile corridor; and should the effect be measured over time, as well? One suggestion was made that if added capacity were provided in smaller increments rather in large projects, some of the negative effects could be alleviated. The comment was made that one issue that had never been resolved was whether all vehicle miles traveled (VMT) were equal or whether all personal miles traveled (PMT) were equal, regardless of trip length. As an example, one participant asked if a 30-mile trip, in terms of its demands on public investment, was more potent a 1-mile trip. It was also suggested that frequently the geographical extent to which transportation effects were studied needed to be increased. A supporting example was offered of an alternative penetrator highway proposal in the Washington, D.C., area. The forecast was to build the highway only far enough into the D.C. area to serve some of the suburban areas but not all the

way into the area. By extending the affected area analysis, however, it was shown that the facility would be attractive for people who, in fact, did want to drive all the way in, adversely effecting neighborhoods and arterials. The discussion dosed with a suggestion that the spatial question in determining the affected area to analyze, as well as the element involved in the effects of added transportation capacity, would be ideal research topics.

The Effects of Added Transportation Capacity on Travel

Ryuichi Kitamura

This presentation attempts to address the question of induced travel and other effects of added transportation capacity. It considers theoretical approaches as well as empirical evidence. The presentation is divided into three parts starting with a brief description of the economic definition of travel supply and demand, followed by a discussion of the paradigm of constant travel budgets, and concluding with the problem of multiple linearity regression.

According to economists, travel demand relates to travel costs. For example, if the cost of time spent traveling to a desired location is too great, fewer people will travel. As travel costs decline, more people will be on the road. On the supply side, travel costs will rise as more people use a facility. Added capacity will result in more use and rising travel costs.

Travel behavior can be considered as resource allocation behavior. Travelers allocate a certain amount of time for travel, and an assumption can be made that when the travel time doubles, for example, the number of trips also doubles. When the cost of travel is reduced by added capacity, more people make more trips. This is the message from the theoretical and economic analysis of added capacity, although it has never been verified.

A theoretical approach to travel demand research presents the concept of the constant travel time budget. A fixed amount of time exists that travelers would like to spend traveling. One counter-argument states that when capacity is improved and when travel costs decline, people will use the time saved to make even more trips. This paradigm generates counter-intuitive results, however. For example, reducing transit fare creates more automobile travel, because the money saved on transit tickets is used for additional automobile travel. This is one of the paradoxes that is derived from the constant travel budget paradigm, and it is one of the issues that should be researched. The constant travel budget, however, is one of the few behavioral paradigms to be developed into an operational model system.

One of the problems with studying the effects of added capacity is the ecological correlation. In the environment in which transportation planners work, everything is correlated with everything else. Within the urban structure there is an activity center or centers; and population densities and land prices tend to decline further away from the center. Houses may be larger and transit service may start to decline at some point away from this center. All these variables are related (income is related to residential choices, and urban density is related to car ownership and household size) and create a highly complex environment in which to plan because all the variables in the system are highly multi-collinear.

It is possible to initiate the modeling process with only one or two variables, but by adding variables so that the model will be more useful and policy sensitive, it may start to fall apart. It can be argued, then, that the solution is either to keep the model simple or to remove all the multi-collinear variables and select a set of relatively independent variables. Either solution has problems and is not very well supported, theoretically.

By definition, induced traffic is related to trip generation, diverted traffic is related to network assignment, transferred traffic is related to mode choice, and shifted traffic is related to trip distribution. Focusing on induced traffic raises several questions. What is the impact of vehicle miles traveled (VMT) on in-

duced traffic? What is the impact of new or added facilities or capacity on induced traffic?

Based on data from 23 cities there is strong evidence that more facilities contribute to longer trip distance, but there is a relationship between trip length and population. The average speed, or network speed, should be lower with more capacity. There is, however, a clear indication that as the average speed rises, trip distances also rise. One problem is that freeway expansion often takes place in areas of urban expansion where the population is increasing. It is difficult to separate the pure facility effect from the growth effect.

One previous study of induced travel added accessibility majors to the trip generation equation, both attractions and productions. The accessibility majors were found to be significantly in school trip production and school trip attraction models. This should not be the case because school trips are similar to work trips and, therefore, should be insensitive to accessibility factors. The same accessibility major was used in a corridor analysis context to establish cause and effect linkages in this multi-collinear environment. The link between accessibility and trip generation had to be removed, however, in order to devise a structure where accessibility influences automobile ownership, which in turn influences trip generation. The results of these studies suggest that there are no linkages between trip generation and added capacity and that there is no induced traffic due to the addition of capacity.

What is important, however, is the growth development and growth effect that a new facility might have. There are several things to consider and study in this assumption. First, it is necessary to have a better understanding of trip timing. One effect of congestion on trip g is, for example, that meetings are scheduled to begin at 10:00 a.m. and end before 3-30 p.m in order for participants to avoid peak travel times. For work trips, people either leave earlier or stay later. If more travel options were available, the response to the work trip would be different. A better understanding of trip chaining is needed, as well. Trip timing and trip chaining are closely related; for example, a person might choose to run an errand during lunch rather than on the way home because of congestion.

Even considering the difficulties in responding to a multi-collinear environment, the complex models now being used can be improved. Erroneous estimates may be produced because the tendency is to produce attractive models with statistics and the right kinds of signals. In an effort to produce these attractive models, variables which may be counterproductive in the long run are often removed. It may be necessary to consider a more complex system of equations in a consistent and statistically desirable manner.

A wealth of data is available from origin destination studies conducted in most metropolitan areas. The quality may not be consistent, but it should be possible to select ten metropolitan areas of different sizes with good data. By applying resources to the data sets, cleaning them up, and supplementing those with missing trip information, for example, the data sets should be comparable to each other in a uniform manner. This process could then be expanded to include land use data and network data. This would be a expensive project, but the results would be a tremendous information source for research. This resource base would make it possible to compare trip timing in cities of different sizes, different densities, and different congestion levels.

There is a limit to the theoretical approaches to studying the effects of added capacity and a lack of consistent observations to support any measurements of the impacts. One solution, the use of the longitudinal panel, provides information on changes in income, behavior, and facility use. This approach would be a beneficial supplement to the traditional four-step model which is not based on change. Combining these two approaches might offer a better set of observations to analyze the effects of added capacity.

Open Discussion

The first question was in reference to the four-step model and the suggestion that improvements to it are needed. Is the planners' understanding of the induced traffic phenomena and added capacity sufficient at this time to warrant adjusts to the four-step model? Or, are additional measurements needed to see if the four-step model is even applicable at this time? Growth and the effects of development are the first order effects, not the induced trip effect; and the four-step process deals only with the induced effects. To include the additional effects will require a five- or six-step model system.

One participant asked how much information was available regarding off-peak trips. In some areas the off-peak travel figures have increased more than anticipated. One participant replied that little information is available on these trips. It was suggested that the increase, in part, may be the result of the increase in the female labor force.

The question was then asked if additional variables, from a behavioral perspective, should be collected. Examples would be the impact that the fear of crime has on transit ridership or the effects of earthquakes on travel behavior. Also, is experiential data beneficial in studying the effects of added capacity? Related to these issues is the time frame and geographical context of the impacts of new facilities. Combined, these elements create the dynamic situation that may be impossible to cover in a traditional, large-scale survey.

Participants discussed the definition of "induced" and its various interpretations. One participant commented that separating a highway's long-term land use impacts from the short term is difficult. Another interpretation of induced traffic is that which is encouraged by added capacity. If a new freeway is built and travel times are improved, people will travel more often. The additional trips are the induced travel.

A request was made to consider the growth stratification that a community might experience. Development traffic will be encouraged by land use changes, but these changes should be separated into those that will occur regardless and changes that are due to the added capacity. Natural growth, it was pointed out, does not consider changes in land use.

The discussion then returned to the applicability of the four-step model to the issues of added capacity. One participant suggested that incremental improvements to the four-step model are needed in the short-term, because it is often suggested that this model is an engineering approach to a social phenomena. Another participant stated that these incremental improvements might be beneficial in the short term, but were they necessary for long-term consideration? It is important, was the reply, that long-term considerations not divert attention from short-term necessity. Long-term modeling objectives can be served with advanced computing and mathematical capabilities that were unavailable before. Several participants supported this view, and the statement was made that both short- and long-term considerations need to be addressed by adjusting existing processes and exploring completely new frameworks for conducting travel demand analysis that go beyond the four-step process. These new frameworks can incorporate elements of chaos theory and mathematics and observe how land use, transportation and travel behavior interact.

It was then suggested that research areas should not be constrained to data sets collected from the narrow American transportation experiences. The dependency of Americans on the automobile constrains the mode choice wi a community. Thus, the overall transportation experience needs to be considered. Short-term questions, such as those related to clean air, need to be addressed; but for long-term economic competitiveness issues such as the dynamics of the automobile-dependent society, the metropolitan structure, and the evolution of constraints on travel behavior all need to be included. Countries with high levels of

affluence such as Canada, Germany, The Netherlands, and Denmark need to be examined. By extending the data set to incorporate communities outside the United States with significantly different mode shares, the impacts of pedestrian and bicycle modes and transit-oriented cluster developments can be better understood. It was suggested that geographic information systems (GIS) will support this kind of research because micro-scale land use and urban form will be easier to incorporate into traditional research methods.

It was then suggested that there are straight forward ways of modeling travel and land use (e.g., the incremental travel forecasting procedure for transit alternatives analysis that is being used in several cities was mentioned). The procedure uses long run demand elasticities based on cross-sectional data. Travel is divided into three components. One is growth in travel due to the changes which would have happened in the region without the major transit or highway improvement. The second is the changes in travel which result from highway improvement and include both land use redistributions and changes in travel and travel cost due to the lowered price of travel. The third is diverted travel, which is how the travel on the particular mode in question distributes itself among the paths in that mode. In this instance, induced travel is really caused by the redistribution of land uses and also by the redistribution in travel as well, including longer trip lengths and increased trip rates. This can be reduced and simplified to be almost incremental elasticity-based by applying single variables.

One participant responded that it is necessary to separate the ability to model from the necessity of gaining a better understanding of what is going on in society. This effort may be a large, data sensitive effort that will not necessarily be elucidated in these models. A concern was also expressed about the practice of ignoring certain types of data, simply because the methods to forecast them are unavailable and, thus, not deemed cost effective. A concerted effort needs to be made to understand the current situation and then determine if the models are appropriate. Two elements need to be distinguished: the societal effects on travel and the changes being made to the transportation system. Understanding travel behavior will benefit the comprehension of the impacts of both these elements on travel.

There are several contextual issues that relate to these types of questions, one participant stated. there is no clear idea as to how much can be known in regard to the overall transportation and urban systems which are so complex with everyone making travel decisions simultaneously. There are interactions which will never be taken into account, and it may never be known how well the models really represent this complexity. No consistent set of numbers are available to tell how large the model errors are; and, even if there were, it would be difficult to determine if the errors were problems in the model, the data, or modelers. Even if these things were known, it might not make any difference. There will always be a need for improvement in models, yet it is not clear when these should be made or why.

There is no question that more research needs to be conducted to improve the understanding of the issues presented here, one participant stated. However, one of the fundamental problems remains that many models currently in use are well behind the typical state of the practice. This may be due to a combination of the lack of finances, lack of staff resources, or carelessness. It was suggested that by merely bringing what has been learned into the existing models, great advances would be made.

The relation between work and non-work trip choices and location was then raised by another participant. In California, for example, so much emphasis is placed on work trips and location choice, that a phenomenon has been ignored, that of people making location decisions that will force them to be auto-dependent for all other non-work trips. The work trip can be addressed through HOV lanes and transit facilities that provide better service for these trips. By choosing to live in areas of single-

family housing and low density, an overall travel pattern is created. Transportation investment decisions make a difference in these residential location decisions.

A question was then raised regarding politics, travel choices, and travel behavior. One participant observed, based on experiences in California, that environmental groups are expressing concerns about transportation investments that cite development as the real issue, not whether a trip is new or redistributed. Transportation plays a role in encouraging development. Focusing research efforts only on redistributed trips will miss the point if the real public concern is developmental impacts.

General criticisms of the current state of travel models were offered by several participants. One general plan was described, for example, that projects three times as much employment as housing. These figures were generated using arbitrary land use inputs without using additional transportation input, thus making the results meaningless. Many large scale models are used incorrectly too, by not feeding congestive travel times into trip distributions. This may result in similar VMT numbers across all development alternatives, even no-build scenarios. It was suggested that the Environmental Protection Agency and the Federal Highway Administration set standards for modeling agencies. These standards should be distinguished between short term and medium term by encouraging the MPOs to implement land use models and the long-term applications and improvements of the four-step model.

The question was raised as to how freight movement relates to the issues being considered. Freight accounts for a large part of traffic in metropolitan areas where interstate commerce moves into and out of ports. The trend toward just-in-time delivery is increasing the amount of product inventory on the highway system and the amount of truck deliveries. How do capacity needs for port access and airport connections relate to work travel? Environmental and economic questions are relevant to both issues.

Several concluding remarks were made, particularly regarding the non-work trip. One of the reasons that induced travel has not been measured is a general failure in understanding non-work travel. Increasing this understanding is a primary concern which may be addressed by developing methods to measure it more effectively. As non-work travel is measured currently, it accounts for up to, 50 percent of peak period travel. Restricting research efforts to the work trip will not be enough when focusing on peak period congestion. Non-work travel must be included for consideration of air quality issues and congestion when studying the effects of added transportation capacity.

Effects of Added Transportation Capacity on Development

Michael V Dyett

By looking back to the transportation modeling activities of the 19, a clear connection can be seen between land use and transportation. Planners are now in an age of standards, following an age of surveys and of models. California law now specifically requires planners to ensure that the circulation element is correlated with the land use element. This means more fitting two maps together on the light table: it involves generating many iterations of model runs to get the right fit and even then the improvements must appear affordable. The trend now is to use different levels of service standards for different land use types, thus requiring that the circulation element fit these varied standards.

Cities and other promoters of transportation facilities are in the land development business, although they often do not fully understand how transportation capacity affects development trends. Highway and transit projects are not just intended to alleviate congestion, which may even be impossible over the long term but are intended to enable urban development to occur.

Added transportation capacity, both improving the existing system and creating new facilities and services, may affect several aspects of urban development. The development location may be affected by added capacity; the effect could be either a distributional effect of or a net addition to the region or corridor. In studies of the Bay Area Rapid Transit (BART) system, the distributional effects are evident, but there was no net gain in terms of the competitive advantage of the area. BART affected the decisions on where to build, but it did not create markets or add to the overall housing supply.

The type of development can also be affected, particularly residential versus commercial and industrial. New highways can increase the viability of shopping centers and mixed use facilities as these centers are capable of drawing critical masses of people, up to 100, 000. Highways can also expand the commute shed and spur housing development. The BART impact studies also revealed a hedging phenomenon. Potential home buyers sought locations that would be served by BART at a later date. In this way, added transportation capacity was used as a form of insurance for the long term, and developers marketed future BART availability as an amenity. Development density and intensity could also be affected. As a site becomes more accessible, there is increased pressure for higher density development. The Galleria area in Houston, Texas, is an example of high density development and transportation capacity. This mixed use area encompasses enough land area to be ranked as the third largest downtown in the state. Proposals for new highway capacity could result in 12 freeway lanes.

Added transportation capacity can also affect development project timing, lease up, and occupancy. Speculation often occurs before transportation projects are approved and under construction; this expectation can influence development construction timing or leasing.

Land use effects are traditionally determined on the basis of changes in accessibility, as well as mobility. These changes in accessibility will affect peak-hour trips. A missing link in the effect of added capacity has been its impact on latent travel demand, primarily related to discretionary, non-work trips. This latent demand may induce pressure for new development or

redevelopment. In urbanized areas the additional capacity alone may facilitate or promote development, while in new growth areas a whole package of facilities, including schools, water, and sewage and drainage improvements are needed.

The setting in which added transportation capacity occurs also affects development. Economic growth potential may vary from region to region, for example, Buffalo compared to San Diego. When the economic growth potential of an area is low, the growth-including impacts of a transportation facility are also low. When there is a strong regional market with a high economic growth potential, the growth inducements and impacts are greater through multiplier effects.

Land use policies such as zoning and growth management requirements limit the effects of added capacity, but they also enable local governments to capitalize on the benefits. In Freemont, California, the goal of the city was to control the type of development adjacent to the BART line. A density floor was set, and the city waited until the market could meet these requirements rather proceeding with lower density developments.

The dimensions of new capacity are another important element when considering impacts. Is the added capacity an incremental improvement to an existing facility, or is it a new highway development?

Location within a region is an additional dimension to consider. If infrastructure facility packages are in place on the urban fringe, added transportation capacity can induce fairly high impacts. In an older central business district (CBD), however, there might be low growth inducing impacts of added capacity.

There are several strategies for dealing with development impacts. The primary key is effective, long-range, comprehensive, coordinated land use and transportation planning supported by local political leaders. Transportation improvements and private development projects that are consistent within these plans should not be automatically assumed to induce growth, nor should they be subject to separate impact analysis for air quality. Also, these pro" should not be subject to mitigation requirements beyond what would be a fair share contribution to citywide improvements and specific off-site improvements not contemplated by the local jurisdiction's comprehensive plan.

The decision-making process of whether to add transportation capacity should focus on how to resolve conflicts through multi-jurisdictional planning. Projects that are consistent with comprehensive plans and zoning restrictions should also be distinguished from those requiring amendments or rezoning. The decision making process should include the following four steps:

1. Design equitable proposals;
2. Facilitate constructive negotiations within the community and between affected jurisdictions;
3. Make decisions based on plans and packages of improvements, not individual improvement projects that are not consistent with land use plans; and
4. Compensate those adversely affected. Two types of questions can be posed for a research agenda: (1) general issues of concern regarding development impacts and (2) more specific questions related to the development process and the role of added transportation capacity in development decisions.

A general consideration includes determining what criteria to use where evaluating development impacts. Safety, mobility, land use compatibility, and the desire to influence modal split are all elements that could be used. Where there are level of service standards correlated with land use, how should through traffic be evaluated in judging local compliance? Under what conditions can new capacity be added without growth-inducing effects? When will new capacity contribute to "economies of agglomeration" or, in contrast, foster more dispersed development? Does it make sense to distinguish improvements designed to cure existing deficiencies from improvements oriented towards new development?

A more specific question related to the development process includes how to determine the developers' perceptions of congestion costs. Do developers consider congestion a cost of doing business that is unlikely to affect project lease-up rates? Or, is the potential for future congestion considered in overall project value? What is the duration of the development effects that is attributable to added transportation capacity? In relation to system performance, are these limited in both geographic area and in time? Does the perceived improvement in mobility from added capacity result in a larger commute shed or greater potential retail market with a long-term economic benefit, or are the results short term in nature?

Mr. Dyett concluded his presentation with a discussion of a recent San Francisco Bay area modeling study which dealt with the effects of the regional transportation plan on land development patterns in 2010. Over this period, the regional transportation improvement plan would fund approximately $15 billion in highway capital costs and $10 billion in transit capital costs. The Association of Bay Area Governments, by using their model and studies for the Metropolitan Transportation Commission, found little difference between the build and no-build scenarios within existing land use constraints. The Bay area is typified as a coastal area consisting of highly regulated communities where the free market does not function in an unconstrained manner. When land use constraints were lifted in the model, new roads had an impact on the distribution of growth. In some counties of the study area, a more dispersed development pattern developed; while in others there was a tendency toward intense development and greater accessibility. The study showed that new roadway capacity could have a greater effect on land use distribution if all land use constraints were removed, which is unlikely to happen. The magnitude and the nature of the effect of added capacity was also shown to be dependent on where the new roadways were located.

Open Discussion

The discussion was initiated by a review of a general plan assessment conducted for Montgomery County, Maryland, in 1987. At that time it was found that the balance between transportation capacity and zoned land use capacity was significantly off. This imbalance was the result of the common practice in the United States of allowing a lot of latitude on commercial zoning& in effect, to give the market the freedom to go where it wanted. The plan assessment determined that the system could not function because of the dramatic imbalance between the number of jobs and houses that was determined by the existing zoning restrictions. Since the assessment, changes in the zoning structure have constrained the amount of employment which can be supported. Additionally, a comprehensive growth policy study which considered various scenarios for growth was conducted. This study showed that it would either be possible to (1) support as many as twice the current number of jobs and houses or (2) support very little growth within the master plan transportation infrastructure. Either scenario depended on the kinds of pricing policies, pedestrian and bicycle accommodations, and travel demand management (TDM) measures that were initiated. The way in which the comprehensive link between land use and transportation planning is implemented is critical to whether or not added transportation capacity induces growth.

One participant commented on the use of models and the results of the BART modeling reports. Reservations were expressed regarding the conclusions that only slight differences were found between the build and no-build scenarios. This result was determined by the property of the models that were used and that they showed little response to the transportation system because the models used for part of the land use forecasting were models that were heavily constrained by external inputs. The external inputs, such as housing stock combined

with the land use constraints, essentially drove the models and determined the output The implication was that very careful studies of model structure and sensitivity need to be considered when applying them to issues of added transportation capacity.

The question was raised regarding freight movement and transportation capacity and development issues. Mr. Dyett responded that freight movement was linked to industrial development plans and ports and airports. These transportation facilities offer an economic advantage for firms involved in the movement of goods, whether they locate near resources or markets or are footloose. If transportation costs can be minimized, an economic advantage can be gained; therefore, firms tend to seek out and bid up land prices that offer this advantage to the extent that local and regional plans provide opportunity. For example, some ports in the San Francisco Bay area have been successful in attempts to spur land development, increase goods capacity and throughput, and attract economic development.

Another participant noted that the level of service (LOS) standard requirements that had been in place in California for several years, and have been copied to a certain degree in the Intermodal Surface Transportation Efficiency Act (L%TA), have probably had more negative effects than positive. The LOS standards have led to down-zoning and development restrictions because they are not based on economic analysis that determine the best, most effective transportation service, but are based on a Department of Public Works process that utilizes little land use or planning input. In Montgomery County, Maryland, an adequate public facilities ordinance has been in use for years that uses both areawide and local area standards for approving new subdivisions. The county permits more congestion in areas where people have alternatives to the automobile. Individual subdivisions are tested to see if they cause local intersections to fail according to local area standards. Frequently, intersection widenings would be required which degraded the pedestrian environment that the county was seeking to improve. In this way policies and LOS standards often work at cross purposes.

Several questions were posed for general discussion: what knowledge about land use is needed to measure the impacts of new highways? What kind of data needs to be collected, and how are the measurements going to be conducted? It was suggested that the panel discuss whether or not they were ready to measure the effect of added capacity; and, if they felt they were not ready, what was needed to get ready.

One participant suggested that they were ready for measurement, although the quality of analysis was not consistent throughout the country. There is an obligation to measure the impacts as there are capital commitments being made with major environmental implications. The comment was made that one problem in measuring impacts is that, first, the affected area or region needs to be defined and matched with an institution. MPOS, for example, do not always encompass the entire region that will be affected by added transportation capacity. This will create difficulties in data collection and measurement.

The issue was raised whether it would be possible to identify the circumstances under which a project or program would not be likely to trigger any sort of development or locational effects. Transportation agencies or air quality agencies can then proceed with confidence that they will not be subject to litigation based on unforeseen impacts. Mr. Alan Pisarski replied that others analyze transportation demand. For example, a retail chain might analyze how far away people are to one store and then calculate where the next store should be located. These sources provide feedback that should be considered when potential impacts are analyzed.

The discussion continued with a comparison of the American, Japanese, and European shopping travel tendencies. Americans, it is claimed, travel greater average distances to shop do Europeans and Japanese. This is a function of the retail structure of the country,

and the United States has been putting pressure on the Japanese to break up the "mom and pop" retail structure and allow for larger regional shopping centers. The Japanese will then become more dependent on longer shopping trips and larger retail aggregations. The Europeans, too, seem to be moving towards a reliance on hyper-markets rather a dispersed retail environment. This creates a different interaction between freight and passenger systems. The European experience is demonstrating that by conglomerating the retail activity, the number of trucks needed to service the hyper-markets is reduced; but it also increases the number of passenger trips to retail centers. The policy tradeoff is whether more trucks in the city are desirable because of a traditional disaggregate retail structure, or are more passenger vehicle trips desirable to a regional shopping center? One participant suggested that because of these issues, the traditional transportation models need to be adapted to represent the more dynamic system of interactions between transportation and business.

The United States manufacturing and service industries are becoming more like the Japanese with an emphasis on the time of delivery and the predictability of service delivery. This has different implications for the industry transportation interaction. An understanding of the change between the private sector and public investment is necessary to design models for the future. The two most important transportation elements to the private sector are bottlenecks and flexibility.

The question was then asked if telecommunications will be considered to be added transportation capacity. Mr. Pisarski replied, yes; the advent of increased telecommunications had influenced the location of business and how traditional business depends on transportation, for example, with just-in-time delivery systems. One of the problems with telecommuting, however, is that by eliminating the trip to the downtown office, and its available amenities, the likelihood of additional trips from home for errands increases. One home-to-work trip downtown is replaced by several non-work trips.

Several issues regarding the political and social aspects of transportation planning and the impact of added capacity were discussed. The difficulty of considering local zoning practices and changes in transportation modeling was one problem, considering the economic inefficiency of local governments. Many of the western states use zoning by initiative, and its impacts are often impossible to predict Most models, too, are developed around the assumption of single-worker households optimizing their location with regard to a single work site. Social conditions have changed considerably, and the two-worker household is prevalent. It was noted that housing prices had risen dramatically, too; and people might be choosing their home location first, then their job location.

The question was raised at what level, project or areawide, should transportation impact models be developed. Traditionally the areawide scale has been used but concern was expressed about the ability of any model to address the small scale impacts of mixed use development and the importance of the non-work trip.

The reply was that there was a considerable amount of new research being done on two-worker households and housing location choice, but little had been implemented in practice. The question of which is chosen first, housing location or employment, is also being studied, as is the importance of recreational opportunities and housing location decisions. There have been few attempts to link these studies with the transportation models, although housing decisions could be an important part of these models. There has also been recent work on business location decisions of footloose industries, the role of telecommunications in industrial specialization, and the breakup of firms. Concern was expressed for the inability to define the limits of a study area as well as the time frame needed for a research program. Only by setting limits can progress be made in evaluating the impacts of added capac-

ity. One of the problems with limits, it was suggested, was that modeling tends to look at things that happened five or 10 years ago. The impacts of telecommunications are significant

at this point in time; but they will be even greater 10 years from now and even with a considerable investment in research efforts, the questions will continue to evolve. Rapid changes in housing and business location decisions, therefore, need to be considered in modeling design.

The comment was made that there was a distinction between short-term research modifications and the long-term research agenda. There can be modifications made to short-term impact studies that will address changing technology on a project-by-project basis. However, for the long-term agenda there is a lack of understanding as to the potential impact of telecommunications. There is a dual problem: one dealing with the necessity for short-term modifications and the other dealing with the long-term understanding and incorporation of rapid changes in the models.

It was suggested that for the short term, modeling will continue as it is already being done; there is little that can change the focus. The long-term agenda is the one that the conference should be concerned with in seeking improvements to modeling tools and understanding. There was general agreement among participants as to the necessity for a long-term focus on the issue but also on encouraging the simultaneous advancement of the current state of practice and the improvement of the state of the art in assessing the effects of added transportation capacity.

Other Effects: Institutional and Financial Context

Sheldon M. Edner

The decision-making process inherent in all aspects of transportation planning (impact studies, transportation systems, travel behavior issues, and land use planning) falls within the context of organizations. This is a concept of decision making in more than three dimensions. This multi-dimensional characteristic of decision making increases the number of variables available for travel behavior prediction.

Those who must make the decisions or introduce them into the transportation processes are the politicians in the urban areas around the country. They must make decisions regardless of the reliability or accuracy of transportation models or knowledge of associated issues such as business location decisions. These decisions are made regardless of the state of planning or modeling practice at any one given point in time. How does the institutional system operate, then, in which these political and transportation decisions are made? Implicit in this discussion, in terms of the planning paradigm, is that regardless of how successful the plan, the integration between transportation, land use, and environment is critical. The institutional legislation of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and Clean Air Act Amendments of 1990 (CAAA) has reinforced this. In that context, it is necessary to consider the current organizational decision making process.

In most urban areas the context for making transportation capacity decisions is not an integrated process. Indeed, most of the institutional context is extraordinarily fragmented and, in many areas, getting worse. Each of the organizations within metropolitan areas has a piece of the pie and feels driven to implement it to their own best interest. San Francisco is one example of this fragmentation. In monitoring a project for Federal Highways, which includes the issue of how the Metropolitan Transportation Commission (MTC) is going to react to and carry out the new responsibilities it will have under ISTEA, major problems have developed. As a result, MTC has been talking to a whole new cast of institutional characters beyond those with whom it traditionally has dealt. All affected participants will talk about how to integrate not only MTC's planning function but also operations issues such as linking together planning and operations to produce the reduction in air emissions which is expected of the transportation side of the equation in metropolitan areas.

One of the most enthusiastic new institutions that MTC is talking with is the California Highway Patrol (CHIP). Becoming involved in the whole process of decision making in the Bay area is extraordinarily important to CHP because it means they finally are given an opportunity to have some input into the design and development of the transportation system which they must control.

Urban areas are more and more fragmented today than ever before. The last decade has essentially been one in which more diversity has emerged in the metropolitan areas with more institutional fragmentation. The experimentation with the private sector involvement in joint development and privatization of transportation services has created not only a larger private role but also many more quasi-governmental and governmental agencies. An examination of the U.S. Census of Governments shows that the number of governmental units across the country is increasing by approximately 3, 000 units of government every five years. The primary growth takes place among special districts, the single-purpose, uni-dimensional gov-

ernmental entity with its own resource base which has responsibility, for example, for sewers and water, in one particular area. The process of identifying the working relationships between these organizations and what they do is more difficult as a result of this fragmentation.

Transportation, in the context of fragmentation, is a single activity that must fit into a much broader set of tradeoffs that are made by a number of organizations working simultaneously towards their individual ends. They do not all work together easily. ISTEA's Section 134 MPO requirements specifies a coordinated metropolitan planning effort and does not even suggest all of the necessary players. Traditional MPOs have been representative of general purpose governments, resulting in the exclusion of a number of individual agencies who, in one way or another, have been responsible for either developing part of a land use planning process or implementing zoning, financing systems, and other aspects of the support systems which make transportation systems operate.

The context of transportation is, in this institutional environment, very fragmented. This fragmentation has led to the basic problems confronting many metropolitan areas and also has contributed to the difficulty of defining induced transportation or additional trips. Because not all organizations share a common definition of what constitutes a trip or trip purpose, each organization may view an additional trip in a very different way. As a consequence this inconsistency makes a determination of whether or not an additional trip is good, bad, or indifferent Portland, Oregon, for example, is zoned for a much higher density than the development it currently exhibits. Those zoning plans are already in place and have been for years. Now that the real estate market is growing, developers are taking advantage of the potential for higher densities and are demolishing single family neighborhoods and building row houses. Residents in those areas are concerned because they do not think the change is appropriate, and they want to maintain the quality of life they have come to expect. The City of Portland's view, however, is to support the higher density zoning opportunities. In addition, other jurisdictions around the metropolitan area have responsibility for parts of the infrastructure process which are not necessarily working in concert with the City of Portland. As a consequence, the whole process has become complex and people are suing one another. The transportation system is becoming part of that complex process in terms of deciding where to build additional capacity.

In effect, there is a ripple effect out from some of the individualized decisions. A number of effects ripple out from improving transportation in a corridor, such as right of way acquisition in terms of the immediate corridor. How far out past the immediate corridor should impacts be considered? The whole corridor preservation component within the current legislation is going to test that proposition; because when an individual project is sited, it may be obvious where to buy parcels of land for speculative purposes. But preserving the land for environmental reasons may constitute the switch to a new corridor, possibly one with a fixed guide way improvement. Broader analysis beyond the center point of the ultimate right of way might be required which would involve a wider range of institutional actors with individual responsibilities for decision making in metropolitan areas.

Another component of the institutional context of added transportation capacity involves tying in the operating elements. Over the years, operating agencies have been left out of the transportation planning picture. In many cases they are after-the-fact participants. The Tri-County Metropolitan Transportation District of Oregon (Tri-Met) got involved in planning for the Portland light rail line system because they recognized, in the early 1970's, that they were going to be left to operate whatever system was developed. Tri-Met hired a consultant to make the case for the system they wanted, in part, because they wanted to participate in its ultimate operation. Other organiza-

tions have not taken that kind of aggressive leadership; and, when given the responsibility for system operation, they have not been prepared. This has created a circumstance where the capacity of the system has either been degraded, or enhanced, in an unforseen direction.

Added capacity also raises a question of design standards. If land use planning is used to reinforce transportation systems so, too, should design components in order to integrate all elements in one overall package. Again, the institutional context within which that takes place is extraordinarily fragmented and continues to remain that way.

What has developed is a more decentralized decision system that somehow must implement the concept behind land use planning and its integration with transport in the environment in a holistic fashion. The implicit message is the sort of normative underpinning of planning that all things should be rational and integrated. But, in the real world, it is not. The institutional decision processes are decentralized and fragmented; and, as a result the individually pieces do not necessarily fit together.

Non-communication occurs the most and a dynamic tension exists between the developing suburban fringe in many metropolitan areas and the traditional core. The exurban fringes outside a metropolitan jurisdictional boundary will often act independently of one another with a tendency to create pressures to develop transport systems to serve their perceived locational advantage. From a political and a broad development perspective, this fragmentation tends to reinforce the notion of decentralized and disaggregate developments that is evident around the country. It also begins to manifest itself in system financing, whether transport, housing, or whatever. The result is an incredible amount of competition for the available financing resources within a given metropolitan area. The disaggregate decision system is mirrored in the financing process. Getting all the players to agree on what kinds of projects ought to be built in a given metropolitan area and to pool their resources to do so is an extraordinarily difficult political process. This lack of regional cooperation leads to the situation represented in the approximately 530 individual projects that are included in the ISTEA legislation. Those projects exist in part because they were not funded locally and, to circumvent local roadblocks to financing, were elevated to the level of national crisis in order to be included in the legislation.

What is happening then is a disaggregate system g to pool resources in a way that it is not prepared to do. MPOs which have the comprehensive oversight for developing transportation plans have not been operating agencies or, in most cases, funding agencies. They have been temporary planning organizations which have had very little institutional context or experience with long term projects and very little authority. As a result, they are going to have to develop additional authority to make se collective metropolitan decisions which to go into reinforcing the transportation programs that need be implemented over the next few years.

Another dimension to this disaggregated, fragmented metropolitan institutional context s an inconsistent time horizon. Each of the organizations operates in its own format and time horizon, which are often different than any other participating organization. To suggest t there is a difference between the transportation planning and air quality planning process, in a technical sense, also suggests differences in terms of timing. Transportation plans re built around the life expectancy of facilities, in some cases, management systems; whereas air quality life expectancies and time horizons are built around a different kind of context. As a result, there is an extraordinary difficulty in simply bringing together that timing in a way which allows the participating organizations to work together. By also integrating the land use planning process, which has an ever longer horizon in some respects, the result is an integrated planning process with entire frames of reference in contexts that are not necessarily consistent.

Within all of this institutional fragmentation is the local politics of a given metropolitan area. Each metropolitan area has its own unique way of doing business. In the Portland metropolitan area the downtown central district was preserved, unlike many other metropolitan areas, based on a significant effort which managed to improve the quality of the downtown. This area is showing signs of deterioration, however. Competition is beginning to emerge from suburban areas which are saying, "We gave earlier, it is our turn." The result is a whole new set of political dynamics playing out between coalitions of downtown developers who want to reinforce the investments made 10 or 15 years ago and the developers on the suburban fringe who want to exploit undeveloped areas and profit from those opportunities. Those coalitions are dynamic and are affected by a broad range of factors including the state of the economy. Unlike much of the country, Portland is a booming real estate market and, as a consequence, is experiencing a great deal of development.

Other intervening issues also interact in any given metropolitan context. Portland has just built a convention center but does not have a supporting convention center hotel in place. This development is tied to its integration with the transit system and the rail fine, as well as being served by various highway corridors. Regardless of the broad general issues of concern with regard to transportation, making that convention center work is a key component of what is going on. It will continue to be a key component, at least for the City of Portland, even though there is a proposal existing in one of the suburban counties for a new sports arena to serve as a replacement for the downtown coliseum. Existing big ticket facilities tend to dictate a large part of what goes on in a metropolitan area largely because the decisions are made by different partners. A justice center was built in downtown Portland using federal highway money because the construction of an outer belt adversely impacted a decrepit jail. That was the basis for the construction of an award-winning justice center funded, in part, by the Federal Highway Administration.

Also unique to the metropolitan context are the social issues that exist. The social environment of many metropolitan areas is changing radically. It has been suggested that it is necessary to take into account the differences in transportation behavior in terms of what kind of trip making decisions people make. The demography of Portland is a unique example. Demographics show that people start out as a family in the center core of the city. When they marry or when they reach a point of creating a household, they tend to move to the outer areas of the city boundaries. When they have a family, they move out into the suburbs. When they are done rearing the family, they move back into downtown. The notion that trip making behavior over the fife of a family is going to remain constant is also open to question. Each metropolitan area, depending on the character of the downtown and the overall livability of that metropolitan area, has its own unique and dynamic trip making behavior patterns.

Los Angeles raises another social question with its diversity of ethnic backgrounds. People in the lower end of the economic spectrum are finding it easier to afford automobiles, to a certain extent, but are now being squeezed in an environment of intense immigration with major impacts on schools and other social systems. The diversity creates even more demand on existing transportation systems and changes the mix of social systems and social service systems. This will have to be a factor taken into account by transport systems.

The relationship between transport improvements in a given corridor and the overall institutional context that exists in the metropolitan area is a synthesis. In some senses, the given, which planners work with in developing overall transit plans for urban areas, is the community value structure that they are trying to enhance with the planning system. This value system is not an integrated whole but is put together by a number of different institutional players in a given metropolitan area. Recogni-

tion of this gave rise, in part, to ISTEA's section 134 planning requirement that requires an MPO to provide a forum. The process of defining community values has not gotten any simpler or more homogeneous over the years, even with the presence of the Section 134 requirement. That led to part of the rationale for making the institutional process of the MPO even more extensive in terms of authority granted, for example, to make decisions based on the authority to withhold federal funds. As a result, the ability to articulate community value on a metropolitan-wide basis and then achieve it through planning processes drawn together in terms of transportation and land use, is still open to question. The process of land use planning is made that much more difficult because of the important question, what kind of urban form is desired? If there is no ideal or clear cut sense of the goal, or a holistic process of achieving it on a metropolitan level, the efforts, in terms of siting transport systems particularly within the context of an environmental dimensions will be much more difficult over the long term.

The argument can be made that a national urban policy exists in disguise. It appears in the context of the CAAA and ISTEA. This raises broad-based questions which deal with a wide range of issues taking into account transportation and housing and investment in a synthesizing way within the context of these two pieces of legislation and in an institutional context of fragmented and decentralized metropolitan areas.

In the short term there are not going to be any Changes in the process of transportation planning.

Open Discussion

The discussion was initiated by a description of the interstate substitution process as an example of a way to overcome the inertia of competing jurisdictions. The interstate substitution process allows different areas to trade interstate freeway segments in order for each area to gain from the overall process and allows for financing to be shifted from one project to another. The process was responsible for the development of the Portland light rail project when over 140 other projects were combined in the process, and all affected parties gained something. For a substitution process to work, individual jurisdictions need to be aware of what they would gain by participating and, for those uninterested jurisdictions, there needs to be incentives to encourage participation. These incentives can be either positive, in the form of local financing, or negative, in the knowledge that other jurisdictions, by participating, will have an advantage over or a negative impact on the non-participant It was suggested that there is a limit to the coordination of affected jurisdictions, however. As a broader cast of characters is required by legislation such as ISTEA and the CAAA, making sure that all the organizations understand the advantages of participation will be extremely important.

Efforts have been made to broaden the geographical definition of a city in order to incorporate a larger tax base that will support a deteriorating inner city. The question was then asked if there were any similar attempts being made to increase the dimensions of an area to include more institutions that would be potential participants in projects adding transportation capacity. Mr. Edner replied that in some cases legislation may redefine metropolitan areas. The boundaries of an MPO will traditionally include all urbanized areas, but it might be different from the census definition of a metropolitan statistical area or consolidated metropolitan statistical area. In defining an area of ozone nonattainment, for example, the boundaries may be different depending on whether or not the governor of the state decides to include nonattainment areas outside the traditional MPO boundaries. Some metropolitan areas might also have more one MPO.

There are few places with formal land use transportation models, one participant claimed. Often, the chosen method of transportation forecasting involved borrowing land use forecasts

and simply applying different transportation scenarios. This method needs improvement because the link between the two elements should be strengthened. Land use forecasting should incorporate transportation improvement impacts down to the local level. Alternative scenarios need to be developed that extend beyond current conditions, perhaps including the impacts of transit or transportation demand management strategies. Various investment circumstances and pricing changes, too, should be considered in transportation and land use models.

It was also suggested that the effects of the fragmented or multiple levels of jurisdictions need to be understood as well, regarding their impact on transportation. One of the problems associated with that approach is that even if all jurisdictions within a region try to cooperate, their individual levels of understanding will often be incompatible. Differences in understanding will be compounded by different levels of financing, analytical capacity, and data collection. This potential conflict presents the question of how to bring an entire metropolitan region together with the same level of competence to approach the issue at hand. A related concern was, given the potential disparity between jurisdictions, how can the EPA assure any level of overall conformity? One suggestion was that an environmental information system (EIS) could be implemented for the overall region to analyze conformity on a program basis rather than on a project-by-project basis.

Transportation professionals, one participant contended, need to encourage changes to the institutional structures that currently act as impediments to planning and implementing added transportation capacity. Developing the data to support changing this fragmented institutional structure will be an important part of the research agenda recommended by the conference. Unless changes are made, the fragmented structure will continue to discourage coordinated land use and transportation planning efforts.

One participant asked what, then, was needed to develop the necessary data to support changes in the institutional structure. It is important, one participant replied, to first look at what the current institutional structure had done. A study of the Washington, D.C., metropolitan area that was prepared for the Transportation Research Board showed that in the sub-regional planning process, three major local jurisdictions had revised comprehensive plans that contained inconsistent transportation and land use elements. This example clearly showed the extent to which non-cooperation would have significant impacts on any future development at the regional level. The level of decision making needs to be equal to the level of impact. One solution would be to give local governments responsibility and make them accountable for issues of consistency. By making the institutional framework responsible, and self-policing the decision-making process will be more explicit and less vulnerable to inconsistencies.

Another point was raised concerning the difficulty in actually defining the type of urban form that was currently in place. How does the existing urban form relate to the institutional structure, and is this urban form a response to social pressures or institutional preferences?

An ongoing research project was described where the influences of institutional factors on transportation and development patterns are being considered. In collecting an international data set and evaluating the travel behavior differences between European countries, an attempt is being made to identify and evaluate the institutional factors. Different policies of housing and business investment also affect location and transportation decisions. It is necessary to stress the long-term nature of comparative institutional research, as well as the necessity for a systematic approach, to ensure that all key variables are identified.

One element of institutional interactions is the concern for system costs. Each institution wants to select the system that will produce the greatest benefit at the lowest cost. To relate this to transportation capacity, it is necessary to consider various alternatives and the costs associated with each. Ultimately, the challenge of the conference is to consider how to convey total system costs and alternatives to affected jurisdictions and the public itself. Fundamental to this task is identifying the strategic options of added transportation capacity and developing tools and models that are policy-sensitive at the macro- and micro-system levels.

The temporal context for the institutions which do that kind of planning will be long term, and transportation planners are still going to have to try and approximate it and deal with it. What is important is determining the relationship, over the long term, of land use planning, environment, and transportation, and integrating, synthesizing, and making them work holistically in a decentralized, fragmented metropolitan area.

Day Two: How to Address the Problem

The opening remarks for the second day of the conference were presented by Dr. Gordon Shunk, Manager, Urban Analysis Program, Texas Transportation Institute. In his comments he restated the original intent of the conference: to identify the principal impacts of added transportation capacity and to determine how to study and incorporate the impacts into models and the planning process. He then summarized the main points from the first day of the conference:

- The impacts of added capacity need to be identified before the modeling process can begin.
- The principal impacts include the growth-inducing effects of added transportation capacity.
- The relationship between travel, air quality, and development needs to be understood and incorporated into the planning process.
- Environmental considerations need to be merged with transportation planning to ensure that two separate planning processes are not addressing the same problems.
- Added transportation can spur development, and new development can cause redistribution of traffic.
- The impacts of added capacity are conditioned by social changes, which greatly affect travel behavior.
- Several questions were raised during the initial day of the conference and were presented for further consideration:

- Will added transportation capacity reduce or increase congestion and air pollution?
- What elements of the transportation modeling process need to be changed? Are the distribution mode choice and assignment models adequate?
- Are there significant latent demand or induced traffic impacts that need to be addressed?
- Should the development and redistribution effects of added capacity be considered key elements in the analysis process?
- Does the present lack of information on latent and induced demand imply that these impacts are, in fact, insignificant?

The following recommendations were presented based on the presentations and discussions from the first day:

- It is important to consider the negative as well as positive impacts of added capacity in any further research.
- More analysis of the extent of impacts needs to be conducted, specifically in determining spatial dimensions and timing (e.g., when the impacts occur and for how long)-* Better information on the effects of added capacity needs to be collected but should not be limited only to data for which forecasts can be conveniently developed.
- The effects of added capacity on freight movement need to be

part of the research agenda.
- The effects on non-work travel and off-peak travel need to be considered, as well.

Environmental Effects of Added Transportation Capacity

John H. Suhrbier

The presentation on the environmental effects of added transportation capacity is divided into five main sections: general environmental concerns and issues, comments on the Clean Air Act Amendments of 1990 (CAAA), description of a land use project in Portland, Oregon, description of project involvement with the State of Washington's legislative transportation committee, and comments on the next generation of travel demand models.

The two levels of environmental concerns are national and local. National environmental concerns include wetlands degradation, hazardous waste, air quality, and climate change. Local environmental concerns include community character, open space, air quality, and the not-in-my-backyard (NIMBY) phenomenon. The influence of both national and local concerns on public sector decision g continues to increase in significance, and transportation professionals need to be responsive to the kinds of solutions that are being developed in response to these concerns. One response is that new and expanded transportation facilities are needed, particularly intermodal facilities. Airports, transit stations, and marine and freight ports need to be considered as well as access transfer facilities.

In order to maintain environmental credibility, existing facilities must demonstrate maximum efficiency before proposing new or expanded facilities. This involves implementing such measures as travel demand management (TDM) and, possibly, congestion pricing. Transportation analysts must predict the impact of these solutions. At a recent meeting of the National Association of Regional Councils during a discussion of employer-based transportation programs, a comment was made that these programs were not worth discussing because they could not be analyzed by the traditional four-step demand models. The response was that perhaps the four-step demand process was irrelevant because it could not cope with the policy alternatives available today. This exchange illustrates how important it is that the analytical capabilities of the transportation professional be enhanced to serve the needs of current national and state legislation.

The traditional way of discussing the CAAA is to list the legislative requirements. There are, however, general analytical requirements that need to be considered. One analytic element is the base year and future year emissions inventory. Inventories in many areas win need to be developed on a spatially and temporally disaggregated basis. Emissions will be examined on an hourly basis over an entire day, which is not consistent with travel demand approaches. Regional vehicle miles traveled (VMT) need to be projected on an annual basis and then the VMT projection must be monitored. It will also be necessary to analyze transportation control measures (TCMs). The CAAA also places an emphasis on market-based economic incentives which will require analysis.

Emissions resulting from increases in VMT or vehicle trips will need to be monitored, requiring a new set of analysis techniques. How will congestion be measured, and how will it be monitored? What is an appropriate measure of congestion on a regional level? How will vehicle occupancy levels be measured in response to employer trip reduction ordinances? These questions, raised by the new air quality legislation, reinforces the need for new analytical techniques.

The issue of conformity and the CAAA suggests a whole new area of analytical requirements. The emissions levels from adopted re-

gional transportation plans and state transportation improvement programs (TIPs) need to be consistent with the mobile source emissions estimate contained in the state implementation plan (SIP). These are the levels against which conformity is measured. Conformity will be monitored at the system level, or for entire programs, rather a project-by-project basis. The changes in conformity monitoring raises several questions. What is the cost in time required to do a legally defensible conformity analysis? Are existing model systems sufficiently accurate on a regional basis, not just a CBD radial highway basis, for purposes of a conformity analysis?

New analytical requirements will also be necessary considering the TCMs recommended in Section 108 of the CAAA. These recommendations include developing high occupancy vehicle lanes, trip reduction ordinances, park and ride facilities, and flexible work schedules. How will the effectiveness of these measures be analyzed wi the context of transportation planning? In many cases it will not be possible to utilize the standard four-step network analysis model sequence. It will not be satisfactory, either, to assume that empirical experiences from isolated analyses of TCMs can be transferred to any other situation.

Existing transportation models must be enhanced and new analytical capabilities need to be developed using pivot point analysis, elasticities, or statistical regressions based on empirical data. To improve existing model systems it is important to know what variables influence highway vehicle emissions. The month and season is an important variable: ozone is a problem in the summer, carbon monoxide in the winter. Transportation analysts, however, traditionally look at spring or fall for a typical sample day. The time of day is also critical, considering the emissions impact of non-peak and non-work trips throughout the day. The standard measurement is VMT, but it is also important to consider whether the emissions are from cold starts, hot starts, or are running stabilized emissions. Estimations of vehicle speed are typically not very accurate in network models; and variables such as acceleration, deceleration, and vehicle operating conditions are often ignored. Important vehicle characteristics to consider are vehicle type, fuel type, vehicle age, vehicle maintenance, and mileage. The location of emissions, too, should be analyzed; where emissions occur is important, whether they are in the CBD, suburb, or elsewhere. For example, it is customary to criticize park and ride lots which can be effective in reducing VMT and running emissions, but they do not necessarily reduce trip end emissions and trip start emissions at the facility.

A highway construction proposal in Portland, Oregon, can be used as an illustration of the necessity for new analytical tools. The proposal is for a circumferential highway in the

southwest region west of Beaverton, extending from Interstate 5 in the south up to Highway 26, near Hillsboro in the west This corridor is approximately 15 miles from the Portland CBD and is currently at the edge of the developed urban area.

Two important aspects of Portland distinguish it from other urban areas around the country. First, there is strong interest in growth management aspects and legislation. And, second, excellent cooperation between the environmental community and the local, regional, and state agencies involved in transportation projects exists.

Two basic objectives drive this project. The first objective is to evaluate a set of alternatives to the proposed western highway bypass and to coordinate this with the Oregon DOT and Portland Metro. The alternatives include land use actions, i.e., observing regional growth patterns and specific small scale activity center developments with a focus on developing transit and pedestrian-oriented designs. The alternatives are also being considered within a broadened context of transportation upgrades for existing roads, transit facilities, travel demand management, and bicycle and pedestrian facilities. The second objective is to determine the appropriate analytical tools that will be effective within this broadened scope. This project uses an interactive and iterative land use transportation analysis system. The specific land use model is Pus DRAM/EMPAL gravity-based models. These two models are linked together in a model sequence with an iteration sequence of five year intervals where the transportation results of one iteration are used to influence the estimated distribution of land use activities, housing, and employment in the second iteration.

Several products will emerge from this process including a set of land use development and transportation proposals. Another product will be an advanced set of models. By simulating the effects of added transportation capacity on emerging development patterns, it will be possible to consider whether there is an alternative to new highway construction. Finally, proposals are frequently presented in terms of a "what if" scenario. For example, if a

proposed development is transit and pedestrian oriented, is new highway construction desirable, as the land use design encourages transit use and walking? New simulations and model enhancements resulting from the Portland project can be used in analyzing this of scenario.

A recent review project for the Washington State Legislative Transportation Commission further illustrates the need for analytical improvements in response to environmental considerations. The project reviewed the methods that have been used for programming and prioritizing transportation actions. Washington's methodologies are considered to be among the best in the country. However, the review revealed several areas where improvements should be considered. First, the procedures need to be responsive to a broader range of policy concerns. Two specific areas identified were growth management and air quality; these need to be treated in a consistent manner. Intermodal coordination needs to be expanded beyond the highway programming process to include other transportation facilities. Investment tradeoffs need to be examined. One tradeoff would be between preserving existing highway and transportation facilities as opposed to increasing capacity. In reviewing project alternatives, a broader range of investment options should be considered. Finally, these programming and prioritization procedures needed to be modified to respond to increased funding alternatives and increased strength in the regional decision-making process.

The Washington review shows a shift from the traditional development of fixed transportation facilities plans to more flexible alternatives that include the possibility of introducing new technologies. A more strategic management of existing resources and a consideration of a variety of factors on an equal basis, such as freight and passenger movement, open space, air quality, and economic development has emerged. The final implication is that these factors must be evaluated in a quantitative manner, not just qualitatively at the programming stage. To do this effectively requires analytical improvements in transportation modeling.

Mr. Suhrbier concluded his presentation with comments on the next generation of travel demand models. There have been many improvements to the four-step modeling process over the past few years, particularly in its adaptation to microcomputers and graphic technology. However, transportation planners still use the same four-step process with the same set of models. This situation presents many questions regarding travel demand models. Is it time to introduce some substantive improvements to the individual models and to the way they are connected? Is it necessary to provide more feedback from traffic assignment into mode choice distribution and generation? Can a broader range of housing and demographic variables be incorporated into the model structure of individual models?

The next generation of travel demand models might consider expanding the range of policy sensitivity, integrating geographic information system technology, and incorporating travel demand management measures. The switch to microcomputers has initiated a decline in model standardization. Will it be feasible to continue to develop an overall standard model system or to concentrate on developing a set of building blocks from which different model systems can be developed that consider regional attributes? Considering all these possibilities, the set of transportation and analytical capabilities that will exist five, 10, or 15 years from now will look very different from the standards of today.

Open Discussion

The discussion session opened with general comments and questions regarding the Portland, Oregon, project. The comment was made that the project was focusing on urban design options that incorporated transit- and

pedestrian-oriented developments. This was different from traditional suburban development options that were exclusively residential and encouraged automobile use. How these design options would blend with the existing urban fabric was being considered in the study project. This focus created a two-scale project scope to look at transit- and pedestrian-oriented developments; one project scope was macro-oriented, and the other was micro-oriented. One important outcome of the Portland project was the comparisons of "visions" of future land use with model results and the attempts to reconcile these two parts.

One participant remarked on the difficulties presented by the questions of scale. Much of the land use visionary planning that has been done at the micro-scale, for example, by Peter Calthorpe, is not easily incorporated into conventional models. The analysis and literature on pedestrian-oriented developments (POD) and transit-oriented developments (TOD) claim that lower vehicular trip rates can result, but these studies do not answer the basic questions presented at the conference. One of the questions is, if a TOD is built with neighborhood shopping, will people actually use it; or win they drive farther to the supermarket to save 20 percent off the neighborhood market prices? This trip might be at off-peak hours, but it might also occur during peak hours. How to incorporate these issues in the models is problematic.

The question of institutional interactions in the Portland experience was also raised. Sections of the proposed road are outside the metropolitan growth boundary, and there has been little coordination between regional policy and state agencies. Similar issues were raised in Florida, it was noted, which resulted in explicit revisions in the state growth management legislation specifying that agencies had to develop plans that were part of the entire state-coordinated planning process.

Another participant said that the Portland proposal emphasized the link between transportation capacity increases and travel demand. The study was designed with a scenario framework for analysis which is important when considering transportation and air quality conformity questions. A key issue was that alternative visions of the community needed to be considered, as the current trends in western Portland would not be sustainable in the future. Alternatives to a major increase in highway capacity in the region needed to be considered. These alternatives incorporated increased bicycle and pedestrian capacity in the community. One of the important findings of the study maybe how much TDM measures have to affect travel prices in order to get the land use models close to replicating the visions.

The question was raised as to what the impacts of the Portland proposal were and how they were going to be measured. The main impact would be how development would occur as a result of alternative transportation investments in transit and highways. Other questions would be how that would affect the distribution of housing opportunities and employment. Would there be significant variations in housing locations if transportation options were provided?

The key to making community scale developments work would be the success of a community shopping facility, one participant said. This was one area where further research would benefit modeling activities. It was then suggested that another area of potential research is housing price response to transportation investments. This response should be incorporated or considered in future modeling systems.

The question was presented regarding how transportation capacity affects development decisions. What, for example, are the costs of intensification? Missing in the current models, it was suggested, was the connection between capacity and development, specifically, the ability to project the reaction of developers to added capacity.

One participant said that the focus of the development and transportation interaction was increasingly centering on the jobs/housing balance. The closer people are to their jobs, the

more travel can be minimized. However, studies in Great Britain imply that a minimum distance between housing and employment is desirable; so perhaps further study of this relationship is needed.

The discussion then focused on the need to examine the forecasting ability of existing models. No serious research has been done since 1980 on the reliability of the forecasts. Part of the problem is the unavailability of complete historical network data sets on which to base a study. It was suggested that there had never been a great deal of concern regarding model testing on a systematic basis and understanding what the capabilities of the model were under different circumstances. One participant replied that, in fact, most modelers knew of the limitations of the tools.

It was then pointed out that one problem with modeling is that the actual facilities being built would last for 10 to 50 years. How can a dynamic world be incorporated into models dealing with long-term facilities? Fuel prices will vary drastically, as will human values. Twenty years ago there was little concern for environmental issues. For this reason, the five year iterative approach to modeling as used in the Portland study would be advantageous. An example of this problem could be found in airport planning. It might be 10 years before an airport is built, and then it will be in use for the next 20. How do elasticity and fuel prices fit into this scenario for modeling purposes? The traditional four-step model would not be adequate for this illustration. Perhaps a solution would be to incorporate micro models for short-term project impacts and then use macro models for the long-term analysis.

It was recommended that micro-scale planning and its effect on trips should be one of the research recommendations from the conference. Specific questions should include the effect that employment and residential micro-planning have on transportation capacity and the effect that pedestrian-oriented development has on capacity?

Additional research proposals could be developed from the 1990 US. Census data on metropolitan area journeys to work. This data supports research on the time element of added capacity impacts. Capacity improvements over 10 years for individual metropolitan areas can be analyzed, focusing on the impacts of small area developments. Development types could be classified as high, moderate, or low growth for time series analysis. Capacity improvements under different institutional frameworks could also be studied. Whether or not the local jurisdictions are amenable to development and added transportation capacity has further implications for modeling.

It is important to understand who in the household works and the location of the work place in relation to the number of total trips made per day. High tech industries, for example, now employ many of the lower income workers in a family, placing them in the overall transportation stream. These workers may not show up on the primary work estimation process used today. Two people per household that commute to work and the housing location decision resulting from multiple commutes have impacts on the transportation system.

One participant then discussed the importance of not separating transportation and development policy from forecasting efforts. The consequences on transportation capacity from either a municipal growth policy, or an anti-growth policy, a high density development policy can be significant. The housing market is a crucial element of growth policies. Housing costs, proximity to employment, and the types of potential occupants impact the transportation network.

The impacts of added transportation capacity, however, may be tempered depending on what kinds of restrictive zoning or growth management polices are in place. Some suburbs are actually shrinking because restrictive policies are either pushing new development farther out on the urban fringe, or even back into the central city. A result of this is a lack of affordable housing in older suburbs which are often major employment centers as well. Transportation capacity improvements in these areas, then, may not have caused increased development For this reason it is important to look back 20 or 30 years at the relationship between capacity additions and development. By doing this, as well as looking into the future at the possible influences of alternative transportation investments and policies, the structural dynamics of the transportation/land use system will be better understood. To do this, it was suggested, it will be necessary to combine micro- and macro-scale factors into the modeling process. One final comment was made that a major impediment to this suggested avenue of dynamic research was that most of the historical data collected by MPOS, for example, no longer exist, or the computer system for which the data were developed is no longer supported.

Forecasting Models

Daniel Brand

In his presentation, Daniel Brand considers the use of transportation models in determining the effects of added transportation capacity. Capacity, however, is not the important determinant of travel demand. The most important determinant is the change in the level of service that influences the consumer's view which, in turn, affects travel demand.

Rail lines are often promoted as being capable of carrying 40, 000 people per hour as opposed to 2, 000 or 3, 000 per hour on congested expressways. While this may be true on some rail lines (e.g., in New York City), it is certainly not the case in other cities. The consumer valuation of level of service is a major influence which affects travel.

Added capacity has major travel impacts in high volume corridors which are currently congested. In large cities and in high volume corridors, the addition of transportation capacity will change the levels of service. However, a capacity increase in a high volume corridor will only cause a return to the former congested state. The results of this capacity increase to a high volume corridor is greater negative air quality impacts a capacity increase to a low volume corridor. Development pressures, which will be greater in a high volume corridor, account for this return to a former state of congestion. When congestion returns to its former state, it can be assumed that the benefits from the trip length increase and the increased trip frequency to higher valued activities at the trip destinations are equal at the margins to the added travel times and costs of those longer and more frequent trips. This describes the conventional derived demand benefit assumption and presents a legitimate framework for evaluating the user travel benefits of capacity improvements by holding constant the assumption that marginal benefits are equal to the change in consumer service. User benefits, which are part of the internalized price of travel, can be valued by allowing individual choice behavior to be presented by the demand curve. Individuals place values on trips, and these can be represented by length and mode.

While this partial equilibrium framework is adequate for evaluating the user benefits of added capacity, it is not adequate for evaluating the air quality impacts, because the new equilibrium of service is unknown. As new development occurs and road patterns change, there will also be changes in emission levels.

Several points need to be made concerning congestion and congestion equilibrium. Congestion is increasingly out of control in metropolitan areas. The automobile system is a classic example of a system where individual choice behavior is paramount. The private interests of the individual, who pays only for the internalized costs of travel, is placed over those of the public or social interests of travel. Each time an individual drives an automobile onto a congested system, the individual generates more aggregate delays and air pollution for others. In economic terms, the marginal private cost of individual travel is significantly less than the social cost of this same travel.

Congestion is the price the transportation system imposes on all users as a result of private decisions to locate in ever larger metropolitan regions and on large plots of land at increasingly farther distances from work. These individual decisions do not take into account the cost of transportation that is imposed on everyone else. Housing location decisions do not internalize the cost of travel. This leads to inefficiency, as the system loses its ability to confront consumers with the real costs of their decision. This is as true in the long term for land use decisions which generate congestion as in the short term for individual travel decisions. By not solving the congestion problem, private

equity in housing is being threatened.

The costs of congestion can be confronted by initiating transportation investments such as intelligent vehicle highway system technology which may serve to mitigate some of the added travel and congestion impacts. Or, consumers may have to pay later for congestion as housing values decline with added congestion. For this reason, social cost questions should be considered in the planning and modeling processes.

Forecasting models are needed to evaluate the travel and air quality effects of added transportation capacity. Travel in metropolitan areas is influenced by many factors which change over time. Direct observation of the effects of change in individual causal variables is not possible, particularly in a situation where transportation capacity is being added and growth patterns and land uses are changing. Multi-variable statistical techniques must be used to separate and measure the influences of causal variables which may affect travel and air quality. The problem, then, is to specify and structure these models properly. What are the correct models to use, adapt, and research? The data generally used to estimate travel demand models are cross-sectional and collected at one point in time. These data represent a general equilibrium supported by the assumption that people have made all of their travel and land use adjustments in response to the levels of service presented by available transportation alternatives.

Travel is usually considered a derived demand commodity. It is desired not for its own sake but is something on which resources must be expended in order to obtain the benefits of the activity at the trip destination. Therefore, the most appropriate way to forecast a derived demand is to forecast the demand for the final good or activity at the trip end. The resources expended on travel will be one of the costs of obtaining that final good or service. Cross-sectional data should be used when forecasting the derived demand commodity, and the appropriate variables are the activity patterns, not the amount of travel.

Activity is a function of many things. In the transportation sector it is a function of the price and service of all competing transportation modes that supply service to a particular area. It is also a function of amenities such as sewer, water availability, schools, and neighborhoods. The appropriate models to illustrate this activity are general equilibrium models which include expenditures on travel and user costs of obtaining trip-end benefits as variables.

One simplification of the general equilibrium model is called a direct demand model. This simplification converts the general equilibrium model to a partial equilibrium model. It incorporates travel mode, purpose, and time period and is a function of the price and service levels on the subject mode and on competing modes. While having shortcomings, the simplification process has advantages. One advantage is that by using existing cross-sectional data, land use changes are modeled.

Simplifying the general equilibrium model is a three-step process. First, the trip table is growth-factored based on changes in activity levels. These changes result from non-transportation factors such as changes in household characteristics, size, or lifestyle. Then, the long run elasticities, or relationships, and the direct demand models are used to forecast induced travel. These forecasts account for population replacement and the experiences of increased use in corridors with added capacity and improved levels of service. They also take into account the short-term changes in travel choices such as frequency, destination choice, and time of day. The third step assigns travel by mode to the facilities g up the subject mode.

The general equilibrium model has been used for several years and has been called an elasticity-based method, or an incremental method. The incremental method has been used to forecast induced travel which is then added to the base trip table. The incremental method can provide a cross check on reality and has many advantages. By using the cross-sectional data that are already available, the three-step

process described here can provide adequate models for forecasting the effects of added transportation capacity.

Open Discussion

The discussion was initiated by remarks from one of the participants regarding the request for simple transportation models. The comment was made that, in general, models require more two or three variables, especially those needed to describe transportation control measures (TCMs). It was felt that an issue more important the number of variables is that the model be carefully structured. The properties of the models themselves need to be examined to verify their validity.

A number of questions were raised regarding added capacity and modeling. What are the likely and most important direct and indirect effects of the major capacity improvements? Why do these effects occur and how are they exhibited? Development pressures and population replacement within the affected corridors need to be considered in model structure. Are there additional induced trips resulting from added capacity? Do people make longer trips or change modes? What are the effects on air quality? It was suggested that while partial equilibrium models are sufficient for assessing user benefits, they are not adequate for assessing social costs such as congestion and air quality. A general equilibrium model is necessary for air quality, one participant added; and conventional models do not take into account the behavioral aspects that need to be included.

One participant asked which modeling practice is currently considered to be the best. Is it the partial equilibrium model even though it does not allow land use impacts to be taken into account? Also, is travel demand really derived from activities and the demand for activities? The reply was that, first, the partial equilibrium model is not always the best model; it would be more convenient to use a general equilibrium model that included forecasts, travel, and land use all in one step. The initial adjustment from the general equilibrium model to a partial equilibrium model is the direct demand model, and the direct demand model is a more logical representation of travel behavior the traditional trip distribution.

The direct demand models should be considered incremental improvements to the existing way of doing things. They fit better the current sequential models that are used, but they are not meant to be a substitute for the ultimate general equilibrium model which forecasts travel at the immediate output of the general equilibrium forecast of activity distributions. These models should be pursued.

Another participant supported this approach and said that given the poor quality of models which are currently being used, it made sense to use a direct demand formulation. The implication of this situation is that modelers and planners need to be prepared for changes in the modeling field as communities realize that to test development options, new analytical tools are required. It was then recommended that a study of the effectiveness of the direct demand model as used in several cities be considered as a research project.

The next section of the discussion centered on the research agenda that should be considered when looking at the effects of added capacity. One participant strongly urged that the research agenda be expanded. There are many questions that the states, MPOS, and local jurisdictions are asking, but the profession is incapable of testing. There are also questions being asked which the MPOs need to be able to answer themselves, given their increased responsibilities in transportation planning. In the past it was suggested that MPOs remain outside the research mode. This situation is changing, and it will be necessary to provide the M?Os with the tools that will enable them to answer these questions.

Another participant added that the application agenda is also important. There are tools and analytical techniques available to provide assistance in the immediate term. The research

agenda will benefit the next generation of conformity analysis, travel forecasters, and land use planners by providing them with better tools; but the current application agenda should not be ignored.

It was then suggested that the research agenda really consisted of two parts: shortrange and long-range research. The long-range agenda will consider how travel forecasting is done; but this may not show results for 10 years, while the short-term needs to support improvements within the next year, if possible. Short-term research can address immediate questions about the four-step process. The fact that several MPOs have experience with the four-step process means that there is value in providing short-term answers to obvious problems. In the longterm, however, it is important to look at the entire approach to travel forecasting and consider the current context within which these questions are being asked. The argument was made that frequently temporary fixes to existing techniques are accepted as substitutes for new work or new approaches. Also, it does not always take 10 years to implement new approaches. The implementation of new, shortterm improvements to an existing model is often easier and more cost effective the continued use of the unaltered version.

A request was then made to enumerate the short-term approaches to the four-step model that had been previously mentioned. One suggestion was the need for accurate estimates of volumes on a link in order to get VMT and accurate estimates of speeds on the link. Estimations of average speeds of traffic, which are unreliable at this time, are needed to study emissions impact. Variance analysis of capacity and performance needs to be conducted. This would allow for better highway system link classification which would provide a better basis for speed and delay calculations. The impacts of available parking and stop signs are not currently understood. The friction between HOV lanes and mixed traffic lanes on a freeway are also areas that need further analysis. Overall, improvements to the four-step model can be made to the performance area in regards to capacity impact.

The next question raised was what level of forecasting should be focused upon, precision, general or specific. Should issues such as specific traffic signals on local streets and pedestrian-friendly urban design be the objective? Or, are these elements too specific for a 20-year forecast? One participant recommended that a general level is preferred, as the more specific forecasts will often be too optimistic and, eventually, unrealistic.

One participant described the speed and volume relationships on a transportation system as chaotic. With advances in chaos theory and the mathematics of chaos, it was suggested that long-range research be implemented from this viewpoint. The conventional four-step model would be inadequate to deal with this approach; but real time monitoring, perhaps with aerial photography, would be an option. Vehicles could be observed in the system in real time to measure volumes and speeds on . One full day of data on a metropolitan system could be captured and compared to the results of a four-step model.

It was suggested that while remote sensing might be a possibility, it moves transportation planning further away from travel demand and behavioral approaches ever before. The approach should be to understand travel behavior and household location decisions at the household level when considering the effects of policy variables on individuals. The effect of parking subsidies and its impact on travel behavior should also be considered.

One participant then questioned the need to get to the level of detail that would be the product of remote sensing. While it would be possible to gain a prediction of emissions based on specific accelerations and decelerations on one link, the demands on the forecasting process from conformity assessment requirements and transportation control measure (TCM) analysis may not require that level of accuracy. Rather, if the transportation research community would work with the air quality commu-

nity and explain the models and their limitations, a more profitable method of dealing with emissions models and travel variabilities could be found.

The importance of basic research on why people make trips was again emphasized by one participant There is still no fundamental understanding of why people travel. How are shopping trips influenced by land use patterns or the availability of opportunity? What happens when transit reaches a higher level of service? The requirements for air quality research supports the need to analyze these issues.

Developers and employers also need to be considered. Better models of future development are needed and a behavioral approach would be appropriate. Future land use pattern and density modeling will be important in generating ideas of what transportation demands will be. For example, most of the new dwelling units in the Portland region over the past 10 years exhibit fundamentally different patterns and densities those built in the previous 30 years. Forming neighborhood clusters into villages or communities with better patterns and densities is problematic because the result can produce fundamentally different transportation demands those being currently addressed.

Several suggestions for the research agenda were then made. It is necessary to be more sensitive to cost and price in transportation models. Most models do not even recognize the share of employees receiving free parking. Person trips should be the fundamental unit of trip generation, rather than vehicle trips, to account for total travel behavior. It is necessary to be sensitive to the proximity of jobs and houses and the transit system. Access to the transit network is important in terms of the quality of walking and cycling, as is the ability of people to satisfy daily needs through short trips.

Other issues that were raised included the need to observe existing developments and the changes taking place as a result of land markets, transportation investments or lack of investments, and social and behavioral factors which are reflected in household demographics and changes. Business location, growth and investment cycles, and spatial elements need consideration, as well. These issues call for a reorganization of the fundamental data structures used in travel demand modeling.

Experimental Design

Peter Stopher

The purpose of this presentation is to try to determine by measurement which of the impacts of added transportation capacity can be identified. There are several impacts that are assumed to take place, such as route changes, mode changes, trip timing changes, destination changes, trip frequency, and trip chaining changes. These are considered short-term responses to capacity increases. Potentially longerterm responses include auto ownership, residential location, employment location, and regional growth changes. The purpose, then, is to determine if any or all of these variables can be measured.

It is important to keep in mind several contextual issues. Given the nature of the source of these changes, a multi-year study is necessary. A number of these effects win not be visible unless the phenomenon is studied over several years. It will also be necessary to deal with time-dependent externalities in the transportation system. It is not possible to change capacity in the system and hold everything else constant for the next five or 10 years while it is analyzed. Gas prices, transit fares, levels of transit service, and other prices wi the urban area will change. Other capacity may be added, and some capacity might be taken away.

As a contextual issue, planners are looking at situations where a significant duration of congestion must exist in order to give rise to the effects that are being studied. There also needs to be a fairly extensive geographic spread of the congestion. Many of the impacts being considered will not occur in a small urbanized area with a localized bottleneck problem, for example, which can be alleviated with additional capacity. Large urban areas with extensive congestion, both by geographic and temporal standards, should be the study areas.

Multiple locations need to be considered, as well. Unless several urbanized areas are studied simultaneously, it will not be possible to sort out what specifically arises from the addition of capacity.

Three categories of experimental approaches should be considered: the case study, attitudinal and preferential surveys, and longitudinal panel surveys.

An example of a case study would be the Century Freeway in Los Angeles which is currently being constructed, or the Central Artery in Boston which would be an actual instance of a significant capacity increase in a very congested corridor. The other categories, attitudinal and preferential and longitudinal panel surveys, are not necessarily exclusive, however. In fact, what should be considered is developing a way to combine several elements of these different categories.

The case study approach is an interesting starting point for any sort of empirical analysis. Obviously, a case study should examine an actual capacity increasing project. It is important to identify it early enough to conduct a set of four surveys of both residents and employers. It is also important to include developers within the list of those to talk with and measure responses from. A series of "after" surveys from the residents and employers is needed in order to follow up on changes taking place. A time span of at least 10 years is required to see long-term effects.

The case study approach is not without problems, however. First there are issues which relate to sampling. Before the project is built, how is it determined who is likely to be the user of that project? These users are the ones to be surveyed both in the before and the after series. It is often difficult to determine who the users will be. Some people will be users of the corridor even before the project is built. If some of the assumptions about the impacts of added capacity are correct, people should be traveling

in the corridor after it has been built who were not traveling there before. Maybe they were not traveling at all, were traveling somewhere else, or were going to other destinations. How can these users be located and the changes that take place measured?

A second issue is time frame. In a 10-year study, there are all sorts of cyclical changes that go on within households. How can these changes be accounted for? Are they actually generated by the changes that they themselves are going through? Would the changes have occurred whether or not the project is built? How are the external changes in the transportation system controlled? A number of other changes g place within the system itself, even within the corridor, need to be controlled if change is actually going to be isolated.

What about the measurement of change? First, there is a problem with the reliability of measuring change. Second, it is necessary to consider what the change is being measured relative to. In this case the interest is in change relative to what would have happened if the capacity increase had not been built. Is it possible to find a control location which is sufficiently like the project location chosen for added capacity so it can be determined how much change would have taken place without the project? The Central Artery of Boston and the Century Freeway corridor of Los Angeles are somewhat unique in their characteristics, but it would be difficult to find a parallel which would allow an assessment of how much of the change can be attributed specifically to the capacity increasing project. Some of the work previously done, for example, on the BART impact in San Francisco, points to a lack of constancy in the system between the before period and the first after-survey. After looking at one before survey and one after-survey, it appears that several changes have occurred within the system in the time period. A case study may not be an idealized situation because of these measurement problems. That is not to say that a case study approach is inappropriate, but alternatives should be considered.

The first alternative to be considered is the attitudinal and preferential surveys where a hypothetical situation is discussed. This measures how people feel they would react under this hypothetical situation. The target population will be people who live in congested urbanized areas. Questions to ask include: What would a capacity increase in this particular corridor mean to you? On the other hand, suppose that capacity did not increase and congestion kept getting worse like it has been doing the last 10 years. How would you respond then?

The first place to start with this approach is a set of focus groups who will identify exactly what should be measured. How can transportation planners interpret the notion of a capacity increase or worsening congestion into language the residents and employers in the area will understand and be able to respond to? One way is by getting people to talk about their problems with congestion by asking them how they might react as congestion gets worse and if there is some way to relieve that congestion.

The idea of a focus group, of course, is simply to help design the main survey and decide how the survey itself should be formed. There are two alternatives. One would be to conduct some simple attitude surveys, which seem to have fallen out of vogue somewhat but were very popular in the 1970's. They may not be a particularly good solution, but simple, straight forward attitude surveys which do rankings, importances, and satisfactions should be used. These will potentially provide some measurement of short-term changes and some indication of the direction of long-term changes. One reason for mentioning attitude surveys is because of recent experiences with similar surveys while interviewing senior management, particularly in the Los Angeles area. The attitude survey was found to be a successful technique for eliciting information from employers which has some sound behavioral basis. Senior management about the future; they may even think about long-term future, and as a result, they potentially respond very intelli-

gently on attitude-type questions.

A second set of surveys to be considered is stated preference surveys. There is no specific definition of the way a stated preference should be done, but the basis for stated preference is to provide people with alternative scenarios (either increasing congestion or a sudden reduction in congestion) and determine, through a tradeoff how they would respond to those changes. Stated preference is gaining acceptance as a method of measurement within the transportation planning profession. It avoids many of the pitfalls which occur and is fairly straight forward in revealed preference measurement where externalities exist that cannot be controlled. That is, in a stated preference survey the individuals surveyed can be controlled as to the specific changes presented to them for which reactions are desired. The respondents can provide the source of tradeoffs of preference necessary to find out how their behavior would change if a congestion-relieving project were built.

The stated preference suggests, then, that there might also be a testable hypothesis. The responses people would have to a capacity increase which relieves congestion may be, in fact, a mirror image of the way they would respond to a continual increase in the levels of congestion. If there is a mirror image and it can be tested as to whether it is a correct modeling of behavior, other potentials are opened up in terms of ways the problem can be studied.

There are several pros and cons to the attitudinal and preferential data. The attitude and preference surveys do not require a specific project setting nor do they involve complex sampling issues. The issue, however, is not to find out specifically which residents of an area would or would not be impacted by a particular congestion-relieving project. Rather, it is important to determine what the residents' current patterns of movement are and then propose to them a relief of congestion in a corridor they are familiar with. This is done with complete control of the externalities. The focus groups can provide a basic design, or a set of inputs, to any survey, whether attitude and preference or case study. The focus group can assist in helping design the survey itself.

There are also some negative aspects of attitude and stated preference surveys to consider. Attitude surveys are not reliable for measuring behavioral intent A considerable amount of literature exists on behavioral intent measurement and how relatively poorly it correlates with actual behavior once the hypothetical situation is actually implemented. For instance, the Dial-a-Ride experiment in upstate New York in the late 1960's and early 1970's and the recent Metro rail ridership experiment in Miami show that there is a relatively poor correlation between stated behavioral intent before the project is built and what actually happens afterwards.

There are also limitations on what can be measured with attitude surveys. Only a certain number of concepts can be comfortably measured with attitude surveys. little is known about the measurement's reliability, but it is probably low with limited quantification possible. The attitude survey will not provide specific and quantitative data for a mathematical model which would forecast the response size expected with a certain amount of capacity.

Stated preference, on the other hand, often involves a fairly lengthy survey design or at least requires several respondents where each one does a partial but overlapping design to keep the design fairly short. Much is known about stated preference in regard to short-term measurement, however, it has not been proven in terms of long-term reliability. That is something yet to be determined since planners have been using stated preference for only a short time. However, on the other hand, stated preference does not require a long duration study. A multi-year study is still necessary but would not require a 10-year study. An adequate design could be accomplished over a period of, perhaps, two to four years.

Considering the time element, it is possible to use longitudinal panels if there is no exclusively conflictual methodology. This considers the possibility of the reversibility of responses to congestion versus responses to increased capacity. An application possibility of a longitudinal panel survey would be either in a case study context where capacity is being increased or perhaps under a situation of worsening congestion where the way people adjust to worsening congestion is analyzed over a period of time.

Both revealed preference and stated preference can be measured with a panel. A word of caution is necessary, because revealed preference (i.e., what people actually do) provides measures of changes in actual behavior. If only one element of the transportation system, for example, is being improved, stated preference is not enlightening, except that it reveals something about the stability of those stated preferences, as no other long-term dynamic, or improvement, is occurring. With stated preference, different measures are considered each time the panel is approached. In a case study context, it is necessary to select the panel before there is a capacity increase so a before survey can be conducted. Repeated measurements by the panel in the "after" period are needed. If this is conducted under worsening congestion, a series of panel surveys under gradually worsening congestion is needed.

Another consideration will be to look at pairing locations. One important aspect is the context within which households operate. The pairing takes place by considering households of similar sized urban areas, demographics, and relationships to the transportation system and congestion. That enables the planner to do pair-wise measurement, particularly if the levels of congestion in the two locations are significantly different. Perhaps the congestion rate is significantly different. It raises some very interesting issues about the ability to measure differences among similar groups of households under differing conditions of congestion.

Some strengths of panel surveys are that the panels do not need to be inclusive of all available demographic groups. Intelligent sampling among demographic groups can be conducted to obtain useful and valuable information by concentrating on certain subgroups of the population. Issues to deal with in any longitudinal panel survey are replacement of panel members and maintaining the interest and completion rates on surveys of panel members, particularly if it will be necessary to go back to them frequently for measurement.

To conduct a panel survey wi a case study context requires a control location. AR that is accomplished by applying the panel to the case study is improving the precision measurement of change within the case study location; it still does not provide information as to what type of change may have taken place in household behavior if the capacity increasing project had not been built. The panel study and any of these studies except the stated preference, will require comprehensive monitoring of the transportation system performance; and not much is known about how to measure performance in many of these instances. Assumptions can be made as to the sort of impact that will occur in terms of the performance on the system; but this does not provide for the exact measurement for that performance. There is a challenge, therefore, as to exactly how to monitor transportation performance in relation to any revealed preference study which is dependent upon either worsening congestion or a capacity increase. The panel survey, to a large extent, becomes much more applicable to residents to employers, although there is some potential to get a few motivated employers involved in a panel. This may have implications for future corporate decisions, depending upon the local situation within an urbanized area and the interest that can be created among the group of employers to be involved in an exercise of this type.

Having considered these three categories of measurement, it is important to consider a comprehensive strategy which includes elements of all of these different pieces - focus groups, revealed preference, stated preference, and longitudinal panels. These elements need to be combined into a comprehensive strategy

for an experimental design. Specifically, a comprehensive strategy could be developed using two longitudinal panels, one of residents and one of employers. The longitudinal panel of residents would include a survey of demographics and characteristics of residents and their households, a stated preference survey, and a multi-day activity diary at the outset so both stated and revealed preferences can be measured. It would also be important to continue the panel with updates of the demographics and characteristics of the household. Certainly there would be repeats of some portion or the entirety of the multi-day activity diary and possibly some other elements of a stated preference survey which might be conducted on a periodic basis. Assuming that a number of companies within the targeted urban areas would want to be involved, a longitudinal panel of employers could be created to conduct a survey of firm and site characteristics, undertake a stated preference survey on the location of the firm at the preset time, and conduct a revealed preference survey on responses to congestion or to capacity increase. Much of the work would be done using face-to-face interviews, which are very effective and generally inexpensive, with a sample of employers. A comprehensive system performance survey would be conducted each subsequent time the panel is utilized.

This is the beginning of a concept of an experimental design that can be initiated and leads to a few conclusions about the objectives of experimental design. First, from this cursory look at methods of measurement it is obvious that a multi-year longitudinal study is required. Also, a case study is not necessarily beneficial; it may have so many complexities that it may not serve the purposes of g to demonstrate what happens when a capacity-increasing project is constructed. The experimental design, however, should use multiple locations, should have comprehensive performance measurements, and should include employers, residents, and developers in the samples. The design of all surveys should be preceded with focus groups. It seems that the ideal would be to combine revealed and stated preference surveys with the use of panels. Longitudinal panels offer many advantages in their precision of measurement and the types of information that can be gained from the study. All of this is just a beginning, however, in forming an experimental design.

Open Discussion

The discussion began with a question about how the focus group and longitudinal approach would predict a change in land use as a result of added transportation capacity. The reply was that these methods will provide measurements from responses by employers and developers about how firms decide to relocate or how developers decide to develop or redevelop an area based on changes in transportation capacity. These responses will not provide the basis for mathematical models but will help answer questions such as which changes in land use really do take place and which changes are large enough to be concerned about. Once significant changes have been determined, the quantification issue can be addressed. The focus group, therefore, is a good starting point to find out what people are responding to. Is it travel time, or is it system unreliability?

One participant suggested that the phenomenon of change is so complex that it would be impossible to remove it from the framework of computer models and computer simulations. The data from the focus group can then be viewed as a section of the model or simulation which can be incorporated into the whole. The goal is to understand the individual phenomenon and use it as a reasonable simulation of the urban space. Another participant agreed that panel data can support larger models, but these models might be very different from the traditional ones in use now.

It was then suggested that in terms of stated preferences of employers, it was effective to ask only that they rank, in order, the issues

related to their location or to development decisions. There was agreement that if a relevant issue was presented to employers, they would be forthcoming with their concerns. Urban area congestion is one example of an issue that is always of concern to employers and developers.

The rank ordering question describes the attitudinal survey, it was suggested. A second question could then be asked of the panel regarding what issues might lead individual panel members to change where they locate or develop. It might be tax increases or it might be congestion. Congestion affects the ability of a firm to market and deliver goods, as well as its accessibility to the employee base. The issue of movement of goods as compared to people is an important one. Certain firms in a panel may be more sensitive to goods movement and delays as compared to employee access.

The comment was made that it was extremely useful to do panel surveys in a variety of cities and communities. It was expressed that one of the major flaws in models developed in the United States is that data have not been collected over the last 20 years in most communities. The panel methodology for data collection is a good place to focus resources to support the evaluation of added capacity, induced travel, the effectiveness of TDM measures, and the effect of changing urban design.

Several comments were then made regarding the makeup of the panel. It is important, it was stated, to increase the size of panel over time. New households need to added and households that move need to retained in the panel population. Frequently, i was noted, panel members were dropped soon as move out of the region. It i important, however, to retain them after move in order to find out what changes a made and how behaviors change in the location. The example was offered of household samples in the Netherlands that grew from 20 municipalities to over 100 as a result of household relocations.

The issue of what constitutes long term regard to a long-term panel study was raised, and the reply was that there may not be a definitive answer. It should be at least several years, was one suggestion; the longer the panel is active, the more data can be collected, which suggests that there is no definitive cut off point, either. The related issue of when results can be expected to appear was then raised. The consensus was that measurements can be taken as soon as the second set of interviews with the panel is conducted. This might be as short a time period as one year if annual surveys are conducted. An important issue related to the timing of results is cost, which is dependent on the number of locations, sample size, and how many demographic groups of households are required.

Several observations were presented from the land development point of view as opposed to that of the transportation planner. First, it is difficult for people to visualize a future condition, especially if this condition will affect their behavior or attitude in some way. This presents a problem: if the change is simple, it may be meaningless; if the change is complex, the sample population may be unable to visualize it. A second problem is that people are willing to provide a response as long as it does not cost them anything. Preferences will be forthcoming as long as a specific cost is tied to the change. Answers and stated preferences may be valid only as long as there is no change; however, change does occur and it occurs rapidly, creating problems for the validity of panel results.

One response to the visualization problem is video technology used to represent alternatives and change. This technique is being used more frequently, and it gives the panel a conceptual sense of the alternatives to consider.

One participant asked whether market research organizations could be used to provide panels and household samples for the kinds of questions being considered regarding capacity changes. It was suggested that while many companies have established panels for market research, they are expensive to access; and the respondents are often rotated as fre-

quently as every three years. Increasing the number and types of questions presented to an existing panel causes fatigue and influences all the responses, making the market research organizations hesitant to assume additional clients.

The question was raised as to whether the information and decisions based on panel data would be enough to satisfy a court. The answer is, probably not, the first goal of the panel, however, was to determine which changes in capacity would be significant enough to warrant quantification efforts. Specific information about the effect of added capacity should not be the entire purpose of the panel approach. However, after a period of 10 years, there would probably be enough information from the panel that statements about the effects of capacity could be supported.

One participant asked if the panel approach was relevant to before- and-after studies. Considering what has been mentioned regarding what can and cannot be measured (i.e., the reversibility between increasing congestion and increasing capacity) the panel approach would be relevant to these studies. Ideally, at some point in the future, one of the locations covered in the panel would actually show an increase in capacity so the effect after the addition could be studied. An important point keep in mind, however, is that some panel members might never be affected by the addition of capacity.

Several participants then made comments on case study design. One of the problems associated with case studies is the tendency to focus on only one case study and assume that it is sufficient. It is difficult to generalize the data collected from a case study. The need was stressed for using a systematic case study design involving multiple case studies. This approach involves more choosing a single case or even five random cases as representative. Cluster analysis and the development of typologies might be useful approaches to this problem. There are also difficulties in doing an adequate job of data collection. For example, major investments are being made in intelligent vehicle highway system () research on real time information systems; but the majority of cities do not keep their traffic signals timed. Another problem is the limited available data on parallel routes. Identifying routes and collecting these data for comparison are expensive. Conceptualizing the data collection scheme is another problem, as is maintaining the data over the lifetime of the project until there is something substantial to analyze.

An additional problem is present in before-and-after studies. Land development encourages long-range anticipatory development, or that development that is spurred by the anticipation of added capacity or new development. The Bay Area Rapid Transit system was discussed for 20 years before construction was started, which encouraged this anticipatory development. No data collection was done that considered this phenomenon.

Concluding comments were made that first encouraged the use of case studies, attitudinal and preferential surveys, and longitudinal panel surveys in developing a basic social science research method to approach the question of added capacity impacts. In light of the larger research questions that are being asked, these approaches should be considered to be sure they are cost effective. They may be only one part of a larger, long-term research agenda.

Finally, it was suggested that the purpose of these approaches is to gain a better understanding of reality. Once this understanding is developed, it will be possible to make better estimates of travel demand.

Closing Discussion

In conclusion, the participants reiterated the major research concerns and offered suggestions for further research. The broad research agenda was discussed as well as specific ideas and possible solutions to questions raised regarding the effects of added transportation capacity. These suggestions were offered:

- The overall research agenda should help quantify the exact nature of the known and unknown induced travel demands associated with increased highway capacity. Defining "induced" will be important for further research and compliance issues.
- There should be a focus on short-run modeling in the research agenda. Geographic information systems (GIS) may be able to Support better forecasting procedures and should be considered.
- More and better data should be collected at the metropolitan level. This research will support volume delay relationships and some of the major inputs to air quality forecasting. Historical socioeconomic data as far back as 1960 need to be collected to determine the effectiveness of forecasts now and in the future.
- Data should be collected on non-home based travel. The link between how a person arrives at work and what kind of non-homebased trips are conducted (during the midday, for example) needs to be examined.
- New variables need to be introduced into the travel demand models. The possibility of using additional demographic variables that influence travel behavior should be researched.

Some suggestions include licensed drivers, vehicle ownership and income, and the proportion of the population living in multiple versus single dwelling units.

- Some of the new variables will be difficult to forecast. First, it will be necessary to determine which independent variables are critical to a greater understanding of the issue of added capacity. When new variables have been specified, such as internal household details, the ability to forecast them accurately is the next step. * The necessity of including business location decisions and business logistics considerations in the research agenda was supported. Modeling also needs to consider freight movement and its impact on transportation capacity and travel demand.
- An effort should be made to model all trips within a transportation system, not only the motorized trips. All household travel, including walking trips, needs to be addressed as do non-homebased walking trips.
- Better models will be the result of a better understanding of travel behavior. It is important to develop a model which is both a practical and a reasonable representation of reality.
- The impact of inter-metropolitan travel, such as that generated by airports, needs to be included in the research agenda. Issues that should be addressed include how many trips are generated to and from airports, and can this travel behavior be documented.
- An effort should be made to conduct more long-range back-casting to determine how effective transportation and land use models have been. Transferring case-specific models from one location to another and then testing for validity should also be considered.
- Many issues of land use policy and land economics need to be included in future transportation models. How can growth management and growth control measures be represented in modeling land availability and land price? A question of how to reflect the capitalization of transit and transportation investments in land use models was also raised.

- Housing preferences by demographic group, both current and projected, need to be included in future models. The decline in real incomes in the United States will have significant impacts on land use and transportation in the future.
- Better automobile ownership forecasting models that are sensitive to changes in the price of automobiles, income, and transit availability need to be developed. The impact of transit stations on automobile ownership should also be considered.
- A critical element in the research agenda should be the issue of model validation. It is important to maintain the urban area database over time to be able to validate any model.
- A suggestion was made that the research agenda be conducted in phases. First, it is important to support the four-step process and enhance it by improving the data applied to it. New elements need to be added in the areas of land use, freight, travel demand management, and coastal processing activities. Research should also be conducted in the application of case studies and panel surveys. Second, major modifications should then be made in the modeling system. This may be a 10-year agenda item. The third phase may be a complete overhaul or replacement of the four-step process.
- The final suggestion submitted was that the environment for

research and innovation needs to be supported because much of the research will take place outside the federal level. MPOs and consultant studies may provide much of the suggested research.

Appendix
Conference Papers

The Travel Effects of Added Transportation Capacity

Gordon Shunk
Texas Transportation Institute

For some time transportation professionals and the community at large have recognized that traffic fills new roadways as soon as they are built. The commonly held belief has been that additional traffic was merely diverted from other facilities. However, transportation professionals have understood that some of that traffic may be new, induced by the improved levels of service where capacity was added. This and other potential effects of added transportation capacity have been largely ignored in the past as insignificant, but are gaining new prominence because of their importance for air quality assessment, congestion management, and growth management.

Four types of effects that result from adding transportation capacity are especially important. Transportation analyses should carefully consider the possible occurrence and potential extent of the following effects of added transportation capacity:

- Additional Trips: New vehicle trips not made previously because of the difficulty or time required for travel are a latent demand that may be stimulated by an improved level of service.
- Longer Trips: When capacity is added, speeds may increase, and a given trip may take less time it had previously. If this occurs, the time saved may be spent making longer trips, such as to a further destination.
- Mode Shift: The possible reduction in travel time due to a capacity improvement may attract people that previously used another mode, such as transit or ridesharing, because of a change in travel time advantage.
- New Development An increased potential for new development may result if travel times decrease. People willing to travel greater distances may select residential, employment, or other activity locations that previously had required too much travel time to reach. This may generate new development and longer trips.

Effects on Air Quality

The concern with travel effects has been stimulated by the 1990 Clean Air Act Amendments which require assessing the effects of transportation improvements on air quality. The question being raised is whether adding capacity is increasing, rather reducing, air pollution. Current transportation planning practice generally assumes that adding transportation capacity relieves congestion, reduces delay, permits travel at more efficient speeds, and, therefore, reduces air polluting emissions.

Few (if any) existing trip generation models consider the effects of added capacity to stimulate new travel. The effects of increased trip distance and mode shift may be accommodated by current travel forecasting and growth allocation models.

It is clear, however, from recent legal proceedings that business-as-usual for assessing the effects of roadway improvements on air quality will no longer be acceptable. Future air quality assessments will have to determine whether the potential emissions reductions attributable to improved speeds and delay will exceed the additional emissions reductions generated by induced traffic. This poses the possibility that all traditional trip generation models, and perhaps other models as well, may need to

be revised. It is critically important to increase understanding of the effects of added capacity on all aspects of travel and to decide if and what improvements to forecasting procedures are necessary in order to accurately assess the air quality effects of added transportation capacity.

Effects on Development Patterns

Capacity improvements may also have important effects for development. The added capacity may permit increased speeds and lower travel times, enabling greater travel distances in a given amount of time. That, in turn, may open new areas for potential development beyond previous limits implied by acceptable travel times. The effect of improved travel conditions on development potential may be accommodated by current development allocation models.

New outlying developments may eventually generate longer trips to and from currently developed areas. Those longer trips may produce more vehicle miles of travel (VMT) which, even if traveled at more efficient s, may produce more air polluting emissions were reduced by the capacity additions.

Growth management strategies that force or permit outlying development may have the same effect on air quality as added capacity. Localities implementing such strategies need to confirm these effects to assure that their control programs are not reinforcing potential air quality problems that may be created by capacity improvements.

Much of this argument is conjecture, so it is especially important to gain a clearer understanding of the interaction of capacity additions and growth management and their effects on development and, in turn, the secondary effects of development on traffic and air quality. these issues must be carefully examined in order to assure that the potential development and air quality effects of adding capacity have been considered.

Effects on Traffic Congestion

Current administration proposals for the federal transportation reauthorization would require that states and local communities establish congestion management programs. The principal goal of such programs would be to reduce motor vehicle travel. The potential traffic-inducing effects of capacity improvements would appear to be counter to that goal. Therefore, it is important to understand how these two potentially contradictory actions function in order to design them to work together.

Adding capacity could be one of the more powerful actions in the congestion management strategy, but how congestion management programs can make the best use of additional capacity must be determined. Designing effective congestion management programs will require an accurate understanding of the nature of traffic using improved roadways, particularly the additional travel that may result.

Candidate Improvements

The capacity improvements most likely to produce the kinds of effects discussed here are new construction on new location and major capacity additions to principal arterial roadways and freeways. Those major improvements seemingly have sufficient potential to induce enough new travel to counteract the anticipated benefits of the capacity improvement. Major transit facility improvements may also demonstrate the effects of interest by diverting traffic from roadways, thereby improving the level of service on those roadways and inducing new traffic.

Investigative Strategy

Careful examination is needed to identify the potential effects of major capacity improvements and to determine why and how those effects occur. Such an investigation would examine the nature and general magnitude of the hypothesized effects in order to determine if

they are sufficiently important for further, more detailed study. This approach will serve to increase understanding about those impacts among the transportation profession, the affected agencies, the respective administration, and the community at large. Such an approach will provide guidance for local, state, and federal officials concerned with transportation impacts and will be a basis for possible future action to address associated problems.

The initial examination will be conducted by a panel of nationally recognized professionals, experienced with the effects of interest and with the forecasting procedures that will be required to estimate those effects. That panel will consider the current state of the art and practice for understanding such effects and will identify causes and measures of those effects. The panel will address the problems associated with estimating such effects, examine the nature and severity of those problems, and propose strategies for dealing with them. The questions to be addressed by the panel would include the following:

- What kinds of transportation improvements may have the effects of interest?
- What effect may be anticipated from those improvements?
- What documented evidence is there to support or deny the occurrence of such effects?
- What do we know/not know about such effects?
- What do we need to know about effects on travel, congestion, air quality or development?

- Is there a need for empirical validation of such effects and their causes?
- How could such effects be estimated?
- What problems may be encountered in obtaining those estimates?
- What improvements may be needed in forecasting procedures to accommodate those effects?

In summary, the proposed investigation should identify the possible effects of transportation capacity improvements, which improvements may have which effects, how those effects may occur, how they might be forecast, and how planning and forecasting procedures might be modified to more accurately reflect such possible effects.

Transportation Investment and Metropolitan Economic Development: A Reconnaissance of Research Availability and Requirements

Alan E. Pisarski

Purposes

This reconnaissance examines the research literature available to support a study of the formative effects of transportation investments in shaping and stimulating urban growth. Its purpose is to establish whether that body of literature is sufficient in depth and scope to permit a research program to be undertaken that would be a definitive synthesis and extension of current understanding of the relationship between transportation facilities investments and metropolitan growth and form.

The primary focus of the assessment is on relatively recent, large-scale transit investments and their formative effects. Other forms of investment, particularly those predominantly oriented to passenger travel (that is, highways and aviation), are also considered. The interest in transit has two elements: in many instances, a part of the rationale and justification for transit investment lies in its presumed power to form land uses more compactly; further, the allied case has been made for the need to form land uses more densely in order to create more successful markets for transit service. In either case, the linkages between transit investment and development need to be better understood.

Conceptual Structure

This topic has a number of intellectual antecedents drawn from geographic theory, sociology, logistics, and micro-and macro-economic analyses that need to be better defined and focused in order to make the current assessment more effective. These are briefly treated below:

The Formative Power of Transportation

The most fundamental explanations of cities, their location, scale, and growth strongly emphasize the formative power of transportation. Perhaps only defensibility had similar explanatory power when large walls were still major factors in military conflicts. Cities often grew up around those points where intermodal exchanges of people and goods occurred fords of rivers and streams, confluences of rivers, end points of navigable bodies of water, natural harbors, etc.

In the modem era more "artificial" (i.e., man-made factors) have played a potentially similar formative role. For example, railroad terminals and stations, although themselves often determined by geographic factors, also provided options for man-made determination of preferred locations. (Much has been made of the power of water resupply points needed to keep locomotives moving across America's west as a creator of towns and cities. In this case, towns were a product of the technologically determined range of the locomotive.) Later, the power of urban transit facilities and highway interchanges to open new land to development and to focus growth have become part of the popular understanding.

A major consideration is that in this new era, human decisions play a far greater role than in previous times when natural determinants were key. This apparent power to form growth raises social, economic, and political questions. Public policy becomes critical. The forces involved - their power and implications - need to be better understood if we are to have the ability to control development.

Although understood, it is less clear that this power to influence development is direct, measurable, and controllable. The power to control adds significant burdens to fully understand the effects of that power. The present study focuses on better understanding of that power.

Documenting Economic Development -An Analogy

One of the dilemmas among transportation professionals regarding this subject is the lack of precision in our ability to explain in economic terms exactly what it is that we wish to measure and understand. The science of economics seems to have a rigorous structure in which these topics are treated, but none that are fully satisfying to transportation practitioners. Attempts to squeeze the subject into accepted modes of economic analysis have led to misunderstanding and confusion.

Perhaps an analogy is appropriate to help isolate the point at issue, if we focus on education, rather than transportation. An attempt to document the economic effects of education would lead in certain predictable paths:

- The construction of schools and colleges can be measured in terms of dollars spent and resources consumed. The effects on the economy in terms of people employed, wages paid, materials used, and tax budgets can be documented to any degree of precision.
- Also, the "going concern" effects can be treated. Employment in the school industry can be measured: teachers, administrators, bus drivers, etc. Total wages, taxes paid, shares of the economy, etc., by the school industry are determinable. Multipliers can be used to assess the further downstream economic effects of the monies put into the economic system.

Neither of these perspectives is the subject of this undertaking. Worth knowing? Yes, but not the current topic. Most significantly, no public official in his right mind would use these economic arguments to make the case for a bigger education budget, but they are the standard basis for transportation spending justifications.

Finally, the central matter of interest is left to be treated, and that is education. What difference does education make? How does the level and nature of education in the labor force affect the relative economic advantage of one place over another? How does it benefit our society? Does the presence of a university and its research facilities and faculty affect the economic power of one place over another? How? Can we quantify these forces, and more importantly, make them work for us?

The hoped-for analogy here is between the thing achieved by the education industry knowledge - and the thing achieved by the transportation industry - mobility and accessibility. It is not the dollars spent in building a subway that is the subject or the economic effects of the employment of a segment of the population in the transit business. Rather, it is the change wrought by the power of transit to provide segments of the population with access to certain places differentially or its ability to raise the ambient level of mobility for everyone. To understand that and to quantify it is the purpose. It answers the question: What is transportation worth?

Redistribution Versus Growth

One issue that causes confusion and argument concerning development effects of transportation investments is the distinction between real, newly-created development effects of investments and merely redistributed development. There are two elements to this issue that warrant discussion.

First, the conflict over new versus redistributed development contains elements of circular reasoning. It is somewhat dependent on the eye of the beholder, i.e., the span of ownership or jurisdiction of those affected by the change. The geographic location of the site for development will be redistributive or new depending on the geographic range of competing

alternative sites. If a new baseball stadium is located in the north of a county instead of the south, it will be "new" for the northern part of the county. It might be seen as redistributive in the county if there was no issue of possible location outside the county. In the region at large it most likely would be seen as redistributive. Nationally, it would be a zero-sum game - a gain in one place versus an equal loss somewhere else - with no likely significance.

If a metropolitan area is competing with other areas for a ball team or an assembly plant, its selection as the site is a new development to the area. Again, the state might see this as merely redistributive if all the alternative sites were within the state.

Ultimately, one might see even national trade consequences as mere redistributions between the U.S. and its foreign competitors in a global sense. "New" then would exclusively mean adding to the world's gross product. It must be recognized that fortunes are made and lost by mere redistributions of economic activities and that every redistribution has both real and new economic consequences for someone.

The second element is that in some cases redistribution may be the goal. The location of transport facilities in order to redistribute activities, to change the density of development, and to re-aggregate certain land uses, may be a conscious policy or intent of a development plan. In this case the issue is not on the competition of who is to be the beneficiary of new development, but rather the net overall benefits expected from redistribution. In the baseball example, the placement of the stadium in the northern segment of the county may be a matter of interest to public policy because of the county's interest in concentrating development in that area or avoiding other areas because of environmental concerns or traffic conflicts, rather any concern about locational competition.

This second point raises key issues for the transportation profession. Public policy may focus on mere redistribution but must recognize that its policies are creating winners and losers. Public policy generates real, new economic effects on someone. Also, beyond economic winners and losers as the result of siting choices, the conscious redistribution of land uses into differing configurations and densities causes very broad, only partially understood, social and economic effects on residents, employers, and visitors that go well beyond the public service costs involved. These must be better understood and more fully incorporated into the calculus of the effects of land use policy choices.

New Economic Realities

The classic concepts that have guided urban theory make extensive use of the power of logistics costs in affecting human settlements, as noted earlier. This focus is fundamentally oriented to the movement of goods and resources rather than the movement of people. Two sets of questions arise:

- What about the movement of people: How does this affect urban development? Are goods movements really more important? What about just-in-time for people? Is raising the general level of ambient mobility in a region a significant factor in attracting new development or retaining it? Does it contribute to regional comparative economic advantage? What about the power of new investment in an already mobility-rich environment? Can it still have significant land-forming power?
- What about the new economic structure of contemporary society with its orientation towards services, marketing, high value goods, high speed delivery systems, etc.? How does this affect the power of transportation to influence development? Classical logistics arguments seem to be highly dependent on industrially-linked economies, with their focus on coal and steel flows, etc. What is their utility in a post-industrial society? Industrial logistics theory explained Pittsburgh, Detroit,

and Chicago. Are new theories or new applications of old theories required to explain Orlando, Phoenix, and San Jose? A useful research effort in this area must be responsive to these areas of concern.

Background and Literature Review

The first difficulty in treating this subject area is in knowing what to call it. At least part of the research problem of the transportation sector in this area is the lack of a shared terminology for the matters of interest. The literature review can range over the topics of economic development, land-use development, impact analysis, efficiency studies, metropolitan planning, and modeling, but extends much further into sociological, geographic, and economic literature. A number of studies provide extensive listings and reviews of some of the diverse literature available. Many of these studies discuss this same concern for a better terminology with which to structure these investigations.

Further problems evolve from the unclear character of the economic effects that are being studied. The general tendency has often been to focus on the impacts of the expenditures made on transportation facilities or the effects of economic activities that go on within these facilities rather the economic influences that flow from the mobility and accessibility benefits provided by the investment in these facilities. These are variously divided into direct, indirect, or induced influences or into primary and secondary impacts (McLeod, PIAT).

A branch of the topic raises interesting issues of perspective. Rather than examining the economic effects of prospective investments as an impacts issue, a DOT study looks at transportation investments as potential tools in a development strategy for a community intent on achieving economic development expansion (National Council for Urban Economic Development). This study raises important questions about the cost-effectiveness of using transport investment as a tool of economic development strategies. Much of the European experience would fall into this category.

The Transportation Research Board Williamsburg Conference on Economic Development raised many of these same issues. Its report will be very valuable to this subject. A paper presented treats the important questions of the influence of transportation investment in the new economic environment (Bell). The paper makes the key observation that transportation bottlenecks are still crucial in that current industries may be just as dependent on effective transportation as those in the past (e.g., American Express versus U.S. Steel), but the new industry is more flexible in that it is more able to relocate in search of improved mobility or other amenities. First, it is leaving only office space behind rather an immense investment in facilities; second, its needs are more generally available: a good airport, good general local mobility, and good highway access versus a port of required depth, double-track rail yards, etc. (the recent move of AAA from Washington to Florida is instructive).

Part of the problem is that the purposes of many of the analyses performed as general studies or specific project studies vary considerably and, thus, modify the scope and rigor of undertakings. Many such studies are promotional in nature, intent on maximizing expected positive effects to attract investors or public support, which affects both their validity and their utility. Such studies rarely exhibit an interest in retrospective tests of the original assertions concerning prospective impacts and are of little value. Only the major before and after studies of transit properties and a few others have been effective in overcoming these weaknesses.

Transit Studies

The dominant efforts in transit studies are those that centered around the building of the major rail rapid transit systems in the San Francisco, Washington, D.C., and Atlanta areas (Rail Transit Impact Studies, DOT). These were generally large scale, extensively funded, multiyear efforts that expressly incorporated a be-

fore-and-after format. In each case, particularly in San Francisco and Washington, D.C., an extensive body of literature was developed over several years. Only the Bay Area Rapid Transit System (BART) study came to a defined conclusion. Washington, D.C. Metro and BART began ambitiously but slowly faded due to a lack of sustained financial support. In many respects these were ground-breaking efforts developing new methods and new perspectives on the character of transit impacts. In several instances this work has been expanded on and added to over the years since the major efforts concluded.

A question can be raised as to why heavy focus was placed on impacts analysis in the transit sector without similar concern for before and after treatment in the highway and air sectors. There are several possible explanations:

- Transit undertakings were very large scale in dollar terms and their supporting demand was primarily prospective. Scrutiny was, therefore, extensive.
- Transit undertakings were system development events rather simply single facility development efforts. Their prospective effects were, therefore, regionwide.
- Transit undertakings came at a time when concerns about the impacts of public investments, both positive and negative, were very high. The trend of the times was to do large scale studies as we learned how to treat these questions. For instance, the Metropolitan Atlanta Rapid Transit Authority (MARTA) program in Atlanta conducted the first system-wide environmental impact study.
- Part of the rationale and justification of these facilities and other transit undertakings were based on prospective development effects and influences on urban form. It was appropriate to assess their effectiveness in achieving those ends by studying their after-effects. Many saw these early undertakings as the first of a large number of prospective heavy rail building programs in other cities to follow. Their success or failure in justifying themselves on the grounds of influencing development trends would be a significant factor in making the case for the entire national program.

BART Impact

The BART Impact study program was a major comprehensive study of the effects of the Bay Area Rapid Transit system as it developed in the San Francisco area in 1972-1974. The impact study was organized in 1972 under federal auspices and completed in 1978, about five years after the inauguration of BART service.

Two elements of the study are pertinent to the current research: "Land Use and Urban Development Impacts of BART, " April 1979 and "The Impact of BART on Economics and Finance, " December 1979.

The major BART findings established the baseline for studies of transit land development impacts conducted later. The study established that BART's greatest strength was in generating advantage for long distance suburban-to-center trips with particular emphasis on weekday peak-period travel, more like a commuter rail system than a traditional subway system. Overall, the fundamental finding in regard to land development was that BART has affected land uses only when supportive conditions - such as zoning provisions, community support, and market demand - are present. In the absence of a supportive environment for land-use changes, the system has had little influence." In some cases its effect was that of". . . coalescing anti-development sentiment in the communities. BART has not reversed declining market trends or initiated developments in areas where demand for new developments are absent." It was found that BART's most notable impacts were in the downtown Market Street area. The influence was seen as more indirect than direct. Other key points were:

- Ridership and other effects were less than expected, primarily because final system

service levels were considerably less than planned.

- The economic growth of the area as a whole has not been affected by BART. "BART generated very little of the major regional economic benefits expected by its proponents."
- The system has encouraged a city-centered concentration of activities and it has provided access to a larger work force in its service area.
- BART played a limited role in new suburban development. Employees seemed to consider BART's availability in evaluating employment options but employers' location decisions seemed little affected by BART's service availability.
- There is no evidence that BART had a permanent impact on property prices or rents.
- "It is too early to determine what BART's ultimate impacts might be."

Discussions with MTC staff indicate that little is currently being done in the area of BART assessment. The recent fifteenth anniversary of the system generated only anecdotal retrospective material (Markowitz).

Metro Impact

The Metro Impact study covered an array of impacts of the new transit system from 1976 to 1985. Most of the study was focused from 1976 to 1982 which is too short term for assessing development changes. Early development impact analyses identified substantial growth in new floor space in almost all land use categories around Metro stations. About half of regional commercial floor space from 1979 to 1982 was within a 15-minute walk of a Metro station. The density of stations in the city center was such that almost any construction in the core area - downtown Washington, D.C., and Arlington-would fall within a 15-minute radius. In the suburbs, however, about 30 percent of commercial development occurred around Metro stations. Those activities most oriented to station areas were offices, hotels, and mixed-use facilities. Projects around Metro stations tended to be twice the size in dollar terms as those built away from Metro station areas.

More recently, an employment study for the period of 1980 to 1985 was conducted. This study used the full 103-mile system as its base for station impacts even though some of them are still not open. This study portrayed a negative image regarding transit's power to change development It noted that while employment in the five-year period grew by 15 percent in the region as a whole, it grew by less 7 percent within Metro station areas. All employment sectors exhibited similar patterns. The emergence of suburban activity centers, the build-out of some station areas, or the shift to service and trade employment were considered possible explanations for this trend. At the same time, Metrorail stations captured 43 percent of the region's commercial development between 1980 and 1986. The Washington, D.C., Metro Impact studies concluded with interesting and useful work in commercial development trends, employment trends, and changes in accessibility but with no definitive conclusions regarding Metro's economic development impact.

Washington, D.C., COG continues to maintain the non-residential construction activity data files that permit it to document metrorelated development activities on a quarterly basis. The first quarter 1990 report indicated that metro stations were significant development attractors with 40 percent of new development around stations.

It is to be noted that COG is currently awaiting UMTA/WMATA funding for an update of Metro development trends. It will also survey work at MARTA, BART, Baltimore, Quebec, and Toronto as part of its assessment. This could provide a major opportunity for extending past impact analyses.

MARTA Impact

Atlanta is a city for which transportation has been a central development force. The original genesis of the city was derived from major railroads coming together. Later, the

conscious development of its airport as a major hub helped make Atlanta the major regional center in the South. Its freeway systems were used to support its central role. Thus, the development of a transit system arose in an environment that understood and appreciated the formative role of transportation.

The development of the MARTA rail system has generally been given credit for arising from the best planning environment of the various before-and-after studies (Davis, Meyer, Price, Cambridge Systematics). Focus of that planning environment was on the station areas' planning and the monitoring of developments around stations. With UMTA assistance, a series of Transit Station Area Development Studies were performed. these were cooperative efforts between the Atlanta Regional Commission, Georgia DOT, MARTA, and the cognizant local government to minimize traffic impacts and maximize development opportunities around stations (Price). A Transit Impact Monitoring Program was developed to evaluate trends over time and establish the extent to which the plans were being implemented. Five station categories were developed for monitoring purposes: high intensity urban, mixed use regional, commuter, -community center, and neighborhood.

The MARTA rail system was originally approved by voter referendum in 1971. The first phase of the system, the East Line, opened in 1979. Overall, 53 miles of the system with 41 stations are planned. A key factor is that about 65 percent of the system operates on existing rail right-of-way.

The land development effects of the MARTA system are open to debate. Some studies have focused on those areas where development has indeed occurred, accepting any development near a station as "rail-related." The Davis study, based on 1985 data, argues that rail transit projects are too expensive "to justify them solely on their merits as transportation systems." Development effects thus become crucial "as a means of justifying these systems based upon the additional economic benefits they can potentially generate." The focus of their research is on "joint development, " meaning joint public-private development linked to transport infrastructure. The study confirmed previous findings that development around rail stations "occurs in conjunction with a strong market situation and supportive zoning policies" (Davis).

A study benefiting from reviewing development in a later time period occurred in late 1988 as a part of an assessment of UMTA programs using case studies (Cambridge Systematics). This study is more elaborate than previous efforts. Rather simply tallying construction in a service area around stations, the study examines the history and behavior of the individual projects. Its findings regarding development impacts in Atlanta, based on extensive interviews, are at best mixed. Given the axiom that transportation is a necessary but not sufficient factor in land development, it is unclear that transit falls into the necessary category. Parallel sites are shown to have developed similarly close to and distant from station areas. Overall, their finding is that "case studies furnish no evidence that rail transit has shaped regional land use" and ". . . has shown mixed and/or modest evidence of rail transit's ability to shape development near downtown and other commercial stations locations." Specifically, the report states "in Atlanta the evidence for this kind of development is incidental."

A number of downtown development complexes, such as the Georgia-Pacific, Southern Bell, and IBM headquarters are closely examined and the concept that MARTA can be credited with their location is evaluated. In all cases the finding was that these structures were highly oriented to the CBD and the predominant orientation of the tenants was to the auto. They cite that developers use the presence of transit as a rationale for project densities in excess of common densities prevailing which " may be causing as many problems as they are solving."

In Atlanta, the current effects of MARTA are open to question concerning their power to

form urban patterns or attract development. The most recent regional plan was revised to reflect the failure to sustain the center's role in development and to respond to the rapid suburbanization of jobs to the north. As in BART, the sense of disappointment and naivete regarding the planners' expectations regarding the formative power of transit is clearly evident.

Smaller Scale Transit Programs

More recent transit investment programs have been less extensive in both absolute and relative scale and, thus, less potent in their ability to form metropolitan land patterns (Emerson). The San Diego light rail system makes no pretense of attempting to form development given its location and structure (UMTA, Transit Impact Studies). Even the larger scale Los Angeles program will have little significance on a portion of the region's activities given the immense scale of the area.

Smaller scale activities such as light rail developments may still be significant in terms of the scale of the communities (e.g., Portland, Sacramento, Buffalo, etc.) in which they are developed (Arrington, Paaswell, CATS). Reports from Portland point to significant land development effects (Affington), whereas early Buffalo impacts appear negligible. However, more recent anecdotal Buffalo experience points to significant resurgence in the downtown area. The most typical area of concern is the power of transit to support and sustain the downtown area's influence. In Buffalo, the issue may have been a trade-off between overall regional service and supporting downtown development. An Urban Land Institute (ULI) study conducted in the early stages of urban transit development identified the factors affecting downtown development and the industries most affected (Black). New programs in Baltimore and Denver would be appropriate for study of economic development trends from the start of a project, especially downtown.

The foregoing indicates the lack of an appropriate metric for determining the characteristics for significant transit land development impacts. Among the factors are:

- Absolute scale. The absolute dollar volumes involved, or the absolute number of people affected by a new project, could define the basis for impacts assessment.
- Relative scale. A key may simply be the prospective share of the region's persons or trips impacted by the investment. A light rail system cannot have the same effects in Los Angeles as in Tucson. This might be expressible in terms of the share of total transport investments in the community represented by the transit undertaking or by the change in the ambient levels of accessibility generated by the new facility.
- Pace of development. The rate at which new population and new jobs are being added in a community affects the ability to

change historical patterns. ff the goal is to change land use by the year 2010 a key question would be what percent of 2010 land development is already on the ground? In areas of the west and south, where annual growth rates are triple and quadruple that of the national average, the opportunities to guide or deflect ultimate patterns will be greater; although those areas are typically the least susceptible to high density patterns. The reverse issue is raised regarding the ability to use transit to turn around a declining area and to generate growth.

A number of studies have surveyed the impact analyses performed in varying cities with a mixed set of reactions, neither uniformly positive or negative (Emerson, Meyer, Cervero, DOT). Many point out the need for other factors to be present in order for transit influences to be effective. Factors such as supportive zoning, land assembly potential, overall growth rates, and other supportive public policies are identified. These factors could overwhelm the transit investment's influence. In some cases public policy might create a self-fulfilling prophecy for the expected development effects by

replicating the thinking of private developers and going where they were going anyway - a similar argument could be made for parking garages. Or, by consciously siting public facilities at the transit investment sites, public agencies might directly cause the effect they were trying to create. Particularly, special zoning bonuses around transit stations as in BART might be sufficient to redirect development to those sites even without the associated transit investment.

With all of the myriad factors involved and the many disparate interests at stake, it is not surprising that conflicting evidence exists. It could be productive to revisit past studies to update findings and to research new modes of studying the effects of investments in new social and economic contexts and in new metropolitan environments.

Highway Studies

Highway impact studies of the 1950's and 1960's are conceptually closer to the transit studies of the early 1980's than they are to later highway studies. Like many of the later transit studies, they were often prospective in nature, seeking to help justify the investment in the facility by extensive description of the economic benefits to be produced (BPR). Land development effects were most often concerned with specific changes along the right-of-way as a result of construction. This is consistent with the time period. In many instances, freeways were new ideas; and the need to gain public support was critical to convince people of the value of freeways in advance (State University; FHWA, Impact of Beltways). Rather sophisticated, high caliber work was done in this period referencing contemporary sociological and ecological research (BPR, State University).

By the 1970's the highway impact studies had changed to a more passive ameliorative tone. The emphasis shifted to minimizing the negative consequences of road development rather than accentuating their positive effects. It almost appears that the positive economic effects needed no further justification or support; rather the critical issue was overcoming negative environmental and social concerns. Noise and air pollution and the need to avoid land use disruptions are significant concerns (FHWA, Social and Economic

Effects 72, 76).

In more recent times, the pendulum has shifted back to economics. This proceeds from the shift to alternative funding sources in some instances and also in response to the nationally recognized need to expand our productivity and competitiveness in the world scene. Two trends are evident. First, the macroeconomic case for highway investment is made based on national economic relationships. These studies seek to identify broad relationships between levels of infrastructure expenditure and levels of the economy (FHWA, current literature). These studies are not facility-specific analyses. The work described by Politano is a hybrid using Bureau of Economic Analysis multipliers to estimate economic effects of highway system plans that expressly include operating cost changes resulting from system development. The second trend is evidenced by specific facility studies often related to facilities aimed at filling in gaps in the interstate system, shortening paths between key points, adding better access for rural development, or adding capacity in congested corridors (Illinois/Missouri DOTS, Wisconsin DOT).

Traditional weaknesses in these studies that need to be overcome relate to the tendency to make the macroeconomic case for highways based on the jobs involved in their construction and operation or their general economic role (Pisarski). In the facility-specific case, the studies increasingly recognize and attempt to quantify the critical economic benefits from improvements in mobility and accessibility (Wisconsin DOT, Indiana DOT). This work needs expansion.

Airport Studies

In many respects, patterns in assessing airport impacts are very similar to those noted above for highways. In the early years after World War II, needs were analyzed extensively

and airports were built. Studies focused on beneficial economic effects. Later the assessments became defensive, like highways, based similarly on noise and air pollution concerns and particularly on negative land use conflicts with adjacent properties.

Recent studies stress the economic importance of airports based on traditional justification methods - jobs involved, revenues produced, taxes generated, etc. The Federal Aviation Administration (FAA) has developed a standardized procedure for airport economic impact assessments. The RIMS II model of the Department of Commerce has been modified and used in a Texas highway assessment (FHWA, current literature). This approach would seem to be equally applicable to transit or highways but is most prevalent in aviation. The approach is prevalent in aviation perhaps because airports are single sites and more individual, private concern exists than for transit facilities of highways. Over 100 such studies have been done (PIAT). The process has been turned into a cookbook activity that tends to inflate the real benefits of aviation. These standardized procedures do not provide significantly useful products to this study. A recent study produced by the Partnership for Improved Air Travel (PIAT) does differentiate these efforts from aviation efficiency studies that consider true travel benefits in a cost/benefit framework, which is closer to the realm of current interest.

Unlike highways or transit, little work seems to have been done in aviation outside very traditional economic impact studies with respect to the effects on development. Research outside government and the operating industry has treated this subject and demonstrated the immense formative role aviation service may have in metropolitan development in the 1990's (Schweiterman, Irwin). One aspect of the aviation picture which may help explain this surprising lack of research activity is that mobility patterns to and from a given city can change dramatically, independent of changes in the physical character of the facilities involved. The shift to hubbing is one example. For instance, a review of the top 50 metropolitan areas in America shows that several hub cities (i.e, Chicago, Atlanta, Dallas) have direct access to almost all of the top 50 areas; whereas other cities of similar population have far more limited access. In the case of smaller cities, an area such as Toledo has access to only 10 of the top 50 areas, while the minihub at Dayton, a city of comparable size to Toledo enjoys far greater direct access to 27 of the 50 cities (Schweiteninan). This must affect their relative attractiveness to certain kinds of industries and activities.

In a forthcoming study, changes in air access in a given city is shown to be linked with the growth in certain service-based industries (Irwin). This provides an important starting point for analyzing the contribution of air service to a region's comparative economic advantage.

Transportation Research Board Possible Tasks

The following task descriptions provide a broad array of useful research opportunities associated with this question. They represent a fairly broad attack on the economic development effects of transportation investments focused on passenger travel investments in the individual modal areas.

It is clear that most of these research tasks are not appropriate for a TRB research undertaking. While there is a great deal of literature available on the general subject, most of it is of a survey character. There is little that provides solid primary data that could contribute to a serious study. Rather a grand global effort, small, focused studies producing tangible contributions to the subject area in specific delimited areas seem most appropriate. Most such work would best be performed by the responsible agencies within the metropolitan areas being studied or in academic environments.

This is an important area, made more important by current concerns regarding national legislation. There are ways in which TRB

can make a contribution in each of these areas. These areas have been identified within the detailed discussions of the following possible research tasks. There is so much research work being conducted in the general area of economic development and transportation investment that it would be appropriate for TRB to play a role in screening and coordinating these research activities.

Task 1: Update and Expand Literature Review

This reconnaissance has sought to identify the available literature in this topical area. The materials identified are presented in Appendix A. If a TRB-sponsored research effort is to be undertaken, the researchers should review the materials identified in Appendix A and expand their research to materials not contained there. Other resources may be available. The literature in this area is variously labeled and has no clear structure or bounds. Some of the literature falls into the areas of economic development, land use, impact analysis, urban planning modeling, and feasibility studies literature. The fields of geography and sociology also have important potential contributions. A number of the references contain excellent bibliographies. To avoid redundancy, bibliographies were not reproduced.

The following areas need further exploration:

- Continued compilation of on-going assessment efforts by the major impact study area cities - The Bay Area, Washington, D.C., and Atlanta.
- Limited or anecdotal efforts by metropolitan areas with smaller transit undertakings - Detroit, Baltimore, Miami, Sacramento, etc.
- Pertinent foreign experience, most notably the Canadian experience with Vancouver, Calgary, Edmonton, and Toronto and experience in Asia and Europe as well. The experience of Lille in France, an apparently successful effort to stimulate development in a declining area, would be a useful counterpoint to the Buffalo and Detroit transit programs.
- Private sector literature can be a very effective resource. The products of the Urban Land Institute and the National Council for Urban Economic Development are effective resources, but many other private associations focusing on developer interests, parking interests, and shopping center interests could be of value. The literature and data sets concerning land tax and assessment experience around transport investment properties is an open area for research.

Task 2. Assessment of Transit Development Impacts

Within this task a number of avenues of investigation need to be pursued relating to transit investments in the United States. The sub-tasks to be pursued are:

Task 2A: Revisit and review major impact studies. Through the 1970's and 1980's a series of before-and-after studies were conducted in areas where our major transit investments occurred: San Francisco, Washington, D.C., and Atlanta. A major body of literature was produced. One of the realities of the studies was that it is difficult to assess development effects, which are necessarily longer term in character, early after system development The last of the systematic national reviews was conducted in 1982. Only the BART study was fully completed. Now, almost 10 years later it would be timely to revisit these programs to assess whether the longer-term effects are more tangible today.

A number of approaches can be considered. First, local planning agencies should conduct retrospective assessments. Second, the current COG activity, "Development-related transit ridership potential at future metro rail stations, to be funded by UMTA, could be the nucleus for such a retrospective effort. This activity could be expanded to be more comprehensive. TRB could provide review, synthesis, and

coordination. A conference could be held to bring researchers together to discuss goals and methods or an expert panel could be formed to monitor the COG activity and to review different approaches for other researchers.

Task 2B: Review of new smaller scale investments. A shift in emphasis to smaller scale transit programs occurred in the 1980's. The ability of transit programs to stimulate or guide development is diminished by their small scale. It is less appropriate to expect significant land-use shifts associated with these activities but an assessment is still worthwhile. A review of current experience regarding the land development effects of these programs could be of value. One important contribution of such a study might be to establish guidelines for small scale assessments based on relationships in area size, project size, etc. Areas of pertinent application include Buffalo, Portland, San Diego, Sacramento, Miami, and Detroit. Useful comparisons would be Vancouver, Calgary, and Edmonton.

As noted, the proposed COG effort will survey some of these same cities. This could provide the basis for an expanded understanding in this area. Otherwise, the available literature would not support a research effort of smaller transit projects at this time.

Research Questions

A review of the transit impact literature leads to the following questions:

1. Does ambient accessibility represent a significant factor in comparative advantage among cities?
2. Can scale effects be identified in the effects of transit or other transportation investment on development? Are they relative or absolute? What are the best statistical measures or indicators of these scale effects?
3. Is there any evidence of the ability of transit investments or other transportation investments to turn around a declining metropolitan situation?
4. What are the key factors governing development or the lack of it around transit stations? Can the elements involved be quantitatively described?
5. What is the power of transit investment to sustain the central city's competitiveness in a region? Are transit cities more centrally oriented? Why?

These questions can be addressed in research undertakings. The following is a brief guide to some of them:

Net Change

Does transit contribute to metropolitan comparative advantage? A key question is whether the presence of extensive transit services provides a significant advantage among cities to attract business or other development. The BART study is the only study to expressly address this question. The BART study found that the system did not change the economic trends of the region. No intercity comparative study has been conducted .

One aspect of the intercity competitive factor is the contribution transit makes to the ambient accessibility in the metropolitan region. Only immense changes cause significant land use effects in today's cities; the effects of accessibility are often a scale effect. Examples of a scale effect are transit investment in New York at the turn of the century when little accessibility preceded it or in western cities with the advent of freeway. (The BART system was only an increment to an already extensive transit system in the Bay Area). On the other hand, transit investment, as in Atlanta, may prove attractive as a signal of a civic interest and as a response to prospective congestion concerns.

Can transit contribute to turning around a low growth or declining area? Of particular focus here are some of the cities that sought to turn around a negative development situation through transit investment. Whereas Washington, D.C, San Francisco, and Atlanta were high growth areas needing transit to respond to problems of capacity, other areas have sought to turn around economic problems by the stimulative effects of transit development. Aside

from the obvious short-term effects of the infusion of large quantities of state and federal dollars, did transit investment help attract new growth or help reverse decline? This is of particular interest in Buffalo where transit investment was a key element in an economic development strategy and to a lesser extent in Portland and Detroit.

Redistributive Effects

Beyond the net change effects on metropolitan area growth potential are the questions of redistributing land development As noted, this can be as crucial as the intercity competitive effects. Two elements to the redistribution question are:

1. Traditional research questions about transit development impacts around stations or along transit corridors; and
2. Broader questions of the power of transit's ability to sustain the influence of the center city in a large metropolitan region where economic forces are acting centrifugally.

Why is the influence of transit around stations so variable? There is a significant body of research literature studying new transit stations with and without growth effects - examples exist of both. Research may be able to clarify why these effects occur in some instances and not in others. Questions also exist about the interaction of transit investment with other factors of development such as special zoning treatment which may have influence independent of transit access. A pertinent area of investigation is to establish the actual causative linkages involved at stations rather the general statistical, evidence; i.e., in a high growth area around a transit station, to what extent was transit a factor in location choices; to what extent are residents, commuters, and shoppers actually oriented to the transit system?

Can transit aid the center city in its competition with the suburban development trend? Transit investment's future role to sustain the center influence of a metropolitan region is a factor that will impact transit investment. Effectively, all major transit investments orient the access opportunities they provide to the center. If they are effective formers of land use, their greatest effects should be felt in the attraction power they generate for the center. That influence can be tested. It must be recognized that the effect of transit access, however effective or ineffective, is acting in a way countervailing other very powerful forces that are tending to reduce the influence of the center. Further, the test of central influence should not be measured in the effects on job locations only. The power of the center for entertainment, recreation, and education must also be considered.

References

1. Donald L. Emerson. A Framework For Analyzing the Land Use and Urban Development Impacts Of Fixed Guideway Transit Projects.

Office of Planning& UMTA. Presented at TRB Williamsburg Conference on Transportation and Economic Development, 1989.
2. Michael D. Meyer. Economic Development Impacts of Rail Investments. Georgia Tech 1984.
3. Robert Cervero. light Rail Transit and Urban Development. APA Journal, Spring 1984.
4. Land Use Impacts of Rapid Transit: Implications of Rapid Transit. Office of Policy, OST, U.S. Department of Transportation, December 1977.
5. J. T. Black, et al. Downtown Office Growth and the Role of Public Transit. Urban Land Institute, Washington, D.C., 1982.
6. Rail Transit Impact Studies: Atlanta, Washington, San Diego. UMTA, U.S. Department of Transportation, March 1982.
7. Metro: Before and After Program, Assorted Materials and Reports, Metro Council of Government, Washington, D.C. 1980-1984.
8. BART Impact Studies. Assorted Materials and Reports, U.S. Department of Transportation, Washington, D.C., 1979.
9. E. Davis, 1. Brown and R. Holmes. Transit-Linked Development A Case Study of Atlanta's MARTA System. RSPA, Department of Transportation, Washington, D.C., 1985.
10. J. A. Page. et al. Catalog of Transit Station Impact Case Studies. RSPA, Department of Transportation, Washington, D.C., 1983.
11. The O'Hare Transit Extension Before and After Analysis. Chicago Area Transportation Study, 1986.
12. Samuel L. Zimmermann. "UMTA and Major Investments: Evaluation Process and Results." Reported in Transit Administration and Planning Research. Transportation Research Board Record 1209, Washington, D.C., 1989.
13. Light Rail Transit: New Successes at Affordable Prices. Transportation Research Board Special Report 221, Washington, D.C., 1989.
14. G. B. Arrington, Jr. Light Rail and Land Use. Tri-County Metropolitan Transportation District of Oregon, 1989.
15. S. M. Edner and G. B. Arrington. Urban Decision Making for Transportation Investments Portland's Light Rail Transit Line. UMTA, March 1985.
16. San Diego Trolley: The First Three Years. SANDAG, UMTA, Washington, D.C., November 1984.
17. T. J. McGean. et al. Assessment of the San Diego Light Rail System. UMTA, Washington, D.C., November 1983.
18. R. E. Paaswell and J. Berechman. et al. An Analysis of Rapid Transit Investment, The Buffalo Experience. U.S. Department of Transportation, 1981.
19. The Impacts of UMTA Programs - Case Studies of Four Urban Areas. Cambridge Systematics, UMTA, Washington, D.C., August 1988.
20. M.D.Meyer. Discussion Paper on Identifying the Effectiveness of Transportation Planning Applications. In Preparation.
21. M. D. Irwin. The Declining Significance of Space. Department of Sociology Louisiana State University. Presented at NCIW Conference on Research Needs for Transportation Investment and Economic Productivity, New Orleans, 1990.
22. M. D. and J. D. Kasarda. Air Passenger Linkages and the Transmission of employment Growth Among Metropolitan Areas. Publication Forthcoming& April 1990.
23. The Economic Benefits of air Transportation. Air Transport Association of America, Washington, D.C., 1988.

24. The Economic Impact of Civil Aviation on the U.S. Economy. Partnership for Improved Air Travel, Washington, D.C., June 1989.
25. J. P. Schwieterman and F. A. Spencer. Alternatives to the

Hub: A Survey of Nonstop Service Opportunities. Transportation Research Record 1094, TRB, Washington, D.C., 1986.
26. J. P. Schwieterman. Airline Routes and Metropolitan Areas: Changing Access to Nonstop Service Under Deregulation. Transportation Research Record 1161, TRB, Washington, D.C., 1988.
27. The Changing Government Roles in Airports. Transportation Research Circular Number 316, TRB, Washington, D.C., 1987.
28. The Economic Benefits of air Transportation. Air Transport Association of America, Washington, D.C., 1988.
29. D. S. McLeod. Recommended Regional Economic Impact Procedures for Aviation-Related Projects. Transportation Research Record 1147, TRB, Washington, D.C., 1987.
30. F.P. Kulka. The Impact of the Genesee County Airport on Genesee County. Transportation Research Record 1025, TRB, Washington, D.C., 1985.
31. New Jersey and the Airlines, Chicago and the Airlines; Michigan and the Airlines; The Airlines Contribution to California. Air Transport Association of America, Pamphlet Series. ATA, Various dates.
32. Current Literature on Highway Investment and Economic Development. Federal Highway Administration, October 1989.
33. The Land Use and Urban Development Impacts of Beltways. U.S. DOT, October 1980.
34. Social and Economic Effects of Highways. FHWA, 1976.
35. Economic and Social Effects of Highways. FHWA, 1972.
36. Highways and Economic and Social Changes. BPR, 1968.
37. A. E. Pisarski. The Nation's Public Works - Highways, Streets and Bridges. National Council on Public Works Improvement, Washington, D.C., May 1987.
38. A Study of the Social Economic and Environmental Impact of Highway Transportation Facilities. State University, BPR, 1968.
39. Richmond Beltway Impact Study. Urban Institute, FHWA, 1978.
40. Chicago/Kansas City Tollway Feasibility Study. Illinois and Missouri DOTS, March 1990.
41. Southwest Indiana Feasibility Study. Indiana DCYI, February 1990.
42. Highway 29145 Corridor Study. Wisconsin DOT, March 1989.
43. A. L. Politano and C. J. Roadifer. Regional Economic Impact Model for Highway Systems (REIMHS). Transportation Research Record 129, TRB, Washington, D.C., 1989.
44. Business Location Decisions. Pacific Consultants, U.S. DOT, November 1980.
45. Transportation and Urban Economic Development. National Council for Urban Economic Development, U.S. DOT, June 1982.
46. A Survey of Techniques Used to Access the Influence of Transportation on Economic Growth Special TRB Panel, Transportation Research Board. Washington, D.C., April 1982.
47. Alan E. Pisarski. Metropolitan and Intercity Transportation Investment and Economic Development. Presented at NCHRP Conference on Research Needs for Transportation Investment and Economic Productivity, New Orleans, 1990.
48. Scott L. Bottles. Los Angeles and the Automobile. University of California Press, Berkeley, 1989.
49. "The Wheel Extended, " Mobility and the Shape of the New Tokyo. Toyota Quarterly. Tokyo, 1989.
50. E. Weiner. Urban Transportation Planning in the United States. Third edition, U.S. Department of Transportation, 1988.

51. Michael Bell. Institute for Policy Studies, The Johns Hopkins University. Bottlenecks and Flexibility. Key Concepts for Identifying Economic Development Impacts of Transportation

Services. Presented at TRB Williamsburg Conference on Transportation and Economic Development, 1989.
52. Ronald E. Grierson. Urban Economics - Readings and Analysis. Little, Brown and Company, Boston, 1973.
53. James Heilbrun. Urban Economics and Public Policy. St. Martin's Press, New York, 1974.
54. Herbert Mohring. Transportation Economics. Ballinger Publishing Company, Cambridge, 1976.
55. John Meyer, et al. The Urban Transportation Problem. Harvard University Press, Cambridge, 1965.
56. Edwin S. Mills. Urban Economics. Second edition, Scott, Foresman and Company, Glenview, Illinois, 1980.

The Effects of Added Transportation Capacity on Travel: A Review of Theoretical and Empirical Results

Ryuichi Kitamura
Institute of Transportation Studies
University of California, Davis

Introduction

The addition of transportation capacity affects potentially all attributes of trips made by urban residents; i.e., time of day, destination, mode, route, and linking of trips. The impact could be more pronounced if unsatisfied or latent demand exists due to congestion (Cambridge Systematics, Inc., and JHK & Associates, 1979). In the long-run, added capacity may influence a household's automobile ownership decision, residence, and job location choice. Firms' location decisions will also be affected. Sooner or later, waves of development start filling the fringe area. It appears most certain that as long as the urban area continues to grow, fringe land with good transportation access will be converted to residential and commercial use. The addition of transportation capacity is one of the key contributors to urban growth.1

Perhaps the most fundamental impact of added capacity is attributable to urban growth stemming from the ability of transportation capacity to support a larger urban population and more extensive non-residential activities. Obviously, this growth has immediate impact on travel demand; an X percent increase in an area's work force would probably lead to an increase in work trips generation by approximately X percent. Possible increases due to changes in departure times, destinations, modes, routes, or even induced trips, appear minute when compared with this primary growth effect.

However, if growth were controlled by strict land-use measures or if growth in an urban area were supported by its political constituencies, then the secondary impacts of added capacity would no longer be a trivial issue. One would need to address the question: What is the trip-inducing effect of added capacity? If highways were not congested, would people go out more often and drive farther? One may also be concerned with the long-term effects of added capacity upon the evolution of an urban area. Would people own fewer automobiles and use public transit more if the capacity of the transit system increased? Would radial expansion of the highway system merely contribute to ever increasing trip lengths?

Neither primary growth effects nor the secondary trip effects of added capacity are thoroughly understood. The growth effects are not incorporated into the standard urban passenger travel demand forecasting procedure in the sense that future land use is predetermined, essentially independent of the future travel demand and supply. Nor are the effects of improved accessibility on trip generation, trip chaining, and trip timing represented in the procedure. This is partly due to lack of theory. Economic theory is often too simplistic to account for the complexity of travel behavior with the multitude of potential behavioral adjustments (e.g., one can change any, or combinations, of trip frequency, destinations, modes, routes, trip timing, and linkages).2 Attempts have been made to construct travel behavior models that draw on broader theoretical bases (e.g., Bhat, 1991; Koppelman and Townsend, 1987; Pas and Harvey, 1991). Yet many steps need to be taken before these efforts can be reflected in the practice of travel demand forecasting.

Furthermore, determining the effect of added capacity is not at all a trivial task because it is concerned with intricately and dynamically interrelated system components: transportation supply system, land use, accessibility, and travel demand. Transportation supply system affects land use, as evidenced by land use development, that seems to inevitably follow the construction of new facilities. Together, transportation supply system and land use define accessibility. Induced trips represent the effect of accessibility on trip generation. Travel demand, in turn, affects the transportation supply system through the planning process. These interrelationships, with built-in lag time, imply an urban system which may be viewed as a labyrinthine "ecological system." Consequently, an attempt to model one variable (i.e., travel demand) as a function of the rest encounters highly multi-collinear explanatory variables, making the identification of each contributing factor's effect impractical.

This paper presents a review of theoretical and empirical results in the literature that shed light to the effect of added transportation capacity. The purpose of the effort is to establish a base from which future research effort can depart. The review of theoretical studies is limited only to those aspects of daily travel behavior for which empirical observations are available. Studies on network assignment and departure time choice are outside the scope of this study. Theories and empirical evidence on long-term impacts of added capacity are also outside the scope except for a review of disaggregate choice models on household auto ownership.

This paper is organized as follows: In the next section several theoretical models and paradigms of urban travel behavior are discussed; The following section offers a review of empirical studies that examine the impact of highways on travel; The next section addresses the limitations of the current demand forecasting procedure, and the last section presents conclusions and future research directions.

Theoretical Approach

A comprehensive theory of urban travel behavior is difficult to establish, perhaps because travel is such a fundamental element of life. Individuals travel for economic, social, psychological, and physiological reasons. Although some aspects of travel behavior (e.g., travel mode choice) may be well described using theories scattered in these academic disciplines, constructing an embracing theory of urban travel and formulating a system of quantitative models has not yet been accomplished.

Examining the impact of added capacity would require a more fundamental understanding of why people travel. It would also require the accumulation of empirical evidence based on exact measurement of each factor's effect. As a precursor of such an endeavor, the discussions in this section focus on microeconomic formulations of travel behavior, the paradigm of cons in travel time budgets, evidence offered by what may be called the "ecological approach, " the effect of accessibility as a general measure of the generalized cost of travel, and some of the difficulties associated with identifying the effect of generalized travel cost on travel (which is a function of the capacity the supply system offers, the spatial distribution of opportunities, and travel demand).

Economic Theory

The cost of transporting goods and passengers plays a critical role in theories of land use and urban development. Theoretical models have been constructed to explain a firm's decision locating its plant, a household's choice of where to reside, or a retailer's selection of store locations. For example, a household may be willing to live farther away from the city center and spend more time commuting if that will allow more residential space to be consumed. The rent per unit space then, must decrease as the distance from the city center increases. Empirical observations often agree with such relations theoretically derived for highly hypothetical and abstract models of ur-

ban areas (for a recent review see Berechman and Small, 1988).

A very fundamental relationship in economics is between supply and demand; the demand for a good increases as its price decreases, while supply increases as the price increases; and an equilibrium will be attained where the demand equals the supply, with the good at an equilibrium price. This can be applied to urban travel by viewing transportation as a consumed commodity (e.g., Wohl, 1962). For illustrative simplicity, let the time cost-of travel be the only cost, and let this cost be proportional to the inverse of the average travel speed in a hypothetical urban area. Then the demand for travel increases as travel speed increases and travel cost decreases. But as demand increases (therefore, as traffic volume increases), speed declines and travel cost increases. The former relation constitutes a demand curve and the latter a supply curve. The intersection of these two curves indicates an equilibrium volume and speed. An improvement to the roadway infrastructure (increased capacity) would lower the supply curve (a larger volume can be carried at the same speed) and the equilibrium point would shift to the right to a larger equilibrium volume, a higher speed, and a lower cost The message is quite clear: Added capacity will lead to an increase in travel with the volume added after the improvement representing "travelers diverted from other facilities, those making more frequent trips, those switching from other modes of travel, or those making entirely new trips" (op. cit., pp. 52-53). This, however, represents a highly simplistic and aggregate approach to travel behavior. People make trips to engage in activities at different locations; the demand for travel is a derived demand and should be treated as such.

In their microeconomic derivation of a gravity model of trip distribution, Niedercom and Bechdolt (1969) depict trip making as a resource allocation behavior. A visit by a trip maker situated at i to a destination zone j, is assumed to produce a positive amount of utility, with repeated Tij visits collectively yielding

Click HERE for graphic.

from i to j. In this formulation, the net benefit to a household derived from travel is maximized Beckmann and Golob also adopt depictions of trip making as a resource allocation behavior and briefly discuss the case where both monetary and time budget constraints exist. 3 The conclusion of their analysis is similar to those discussed above: Trip frequencies will increase as the generalized cost of travel decreases. 4

Travel Time Budgets

When trip making is viewed as a resource allocation behavior, then the total travel resource that can be allocated becomes a primal driving factor. Zahavi proposes an alternative travel demand forecasting procedure which explicitly incorporates time and monetary budgets for travel. Zahavi's paradigm of constant travel time budgets and empirical observations on which it is based (Zahavi and Talvitie, 1980 and Zahavi and Ryan, 1980) have led to extensive debates (e.g., Downes and Emmerson, 1983; Supemak, 1982, 1984; Zahavi, 1982; Van der Hoom, et al., 1983). Zahavi's approach is one of a few principles of travel behavior that have been developed into operational forecasting systems. Its use has been alluded to recently by Stopher (Applied Management and Planning Group, 1990) as a possible approach to accounting for the travel impact of added capacities. A close review of the approach appears to be warranted.

The Unified Mechanism of Travel (UMOT) model is proposed as an alternative to traditional approaches to urban passenger travel and demand-supply relationships (see Zahavi and McLynn, 1983). The backbone of the UMOT model is the hypothesis of the constancy in household travel budgets. "The UMOT model maximizes the daily spatial and economic opportunities per household, represented by the daily travel distance, under explicit constraints. The constraints are the daily travel time and money expenditures per traveler and per household, respectively. These travel budgets have been found to display consistent regularities and to be transferable both spatially and over time" (op. cit., p. 137). This formulation of trip making as a travel distance maximization process is based on the viewpoint that travel itself produces utility; therefore, savings in travel time and costs will be used for more travel. It is, however, noted without further clarification that "both the travel time and money budgets are state variables that change during each iteration" (op. cit., p. 138).

These assumptions underlying UMOT yield many interesting insights, e.g., households respond to an increase in auto monetary travel cost, not by reducing the level of auto ownership but by choosing to hold automobiles of lesser quality, or of lower "car factor" values. The car factor represents the quality of the vehicles that tend to be owned by households in each income group, or "the type of car associated with each income group, namely above or below a standard car, where the value of 1 ... signifies a standard car" (op. cit., p. 144).

At the same time, these assumptions seem to produce counter-intuitive indications. For example, Zahavi and McLynn report that higher income households are able to satisfy their travel needs by increasing vehicle ownership levels, but "low-income households, on the other hand, cannot satisfy the demand for car travel to all their travelers. Furthermore, since the increasing number of travelers have to be satisfied by other modes than car, say buses, all which require travel expenditures, car ownership levels actually decrease with increasing household size" (op. cit., p. 145). Or, "gasoline consumption may increase, not necessarily decrease, at some point along the increases in car unit costs ...." The reason for this somewhat unexpected result is that decreases in the car factor (namely, increasing the average age of cars) result in increases in gasoline consumption" (op. cit., p. 149). Perhaps the most paradoxical is the result, "a reduction of bus fares ... may allow low income travelers the transfer of the freed bus fares to car travel ... conventional wisdom tells us that bus fare reductions should attract car travel to bus travel, while the UMOT model predicts otherwise" (op. cit., p. 151). In other

words, when bus fares are reduced low-income travelers can use the resulting savings for auto travel. While Zahavi and McLynn maintain that this is an example of the Giffen effect with bus trips being an "inferior good, " no empirical evidence is offered in support of the result.

It is not difficult to imagine that the UMOT model system is at best controversial. Downes and Emmerson (1983) note that "the effects of trip characteristics on trip rates are not fully understood" and present a study that examines the effect of improved travel speeds on the trip length and frequency. They use 1976 large scale household interview survey results from 12 municipalities of varying populations and sizes. The study separately analyzes a sub sample of 32,000 individuals who "only traveled internally" within study areas (op. cit., p.174) and concludes that the total travel expenditure decreases as travel speed increases for those internal travelers, while it increases with speed if external travel is included.

The results thus cast doubt on the assumption of constant travel time expenditure. The study, however, does not explicitly state how the average speed was defined for each traveler. If the average speed is defined as the total distance traveled by a traveler divided by the total time it took (which is suggested by the discussion on p. 176), then this variable is endogenous and the results by Downes and Emmerson could be seriously biased.

Van der Hoorn, et al., (1983) acknowledge that the UMOT approach is "very appealing to policy makers and researchers because it is conceptually simple and robust, the data requirements are low and the model is easy to compute on a micro computer" (op. cit., p. 156). However, their effort to implement the model for the Netherlands has led to the identification of several limitations in the model, questionable mode use elasticities with respect to their costs, and a finding that the auto ownership component is "too simplistic" (op. cit., p. 168). In his comments to Vander Hoorn, et al, Zahavi notes that most of the limitations are accounted for in the latest version of the UMOT model.

Supemak (1982) points out the inconsistency that exists among various measures of travel budgets (or, expenditures) and cites empirical observations that contradict the hypothesis of constant travel budgets. In particular, Supemak reports that trip rates are "more regular and stable" travel time budgets, supporting the conventional sequential approach that starts with trip generation analysis.

It is indeed unfortunate that Zahavi passed away before he was able to complete the UMOT Model. It is yet to be determined whether the above counter-intuitive indications from the UMOT model are logical consequences of the assumption of constant travel budgets or mere aberrations resulting from a forecasting system yet to be completed.

Accessibility and Added Capacity

An accessibility measure, representing the relative ease of reaching opportunities in an urban area from a specific area within it, may be interpreted as a general indicator of the cost of travel. Then, applying the economic principle discussed earlier, residents in a high-accessibility area should tend to travel more, not necessarily in terms of travel time or cost, but in terms of trip rates or VMT. Theoretically it is expected that trip generation is positively correlated with accessibility.

Added transportation capacity, whether by means of additional freeway lanes, HOV lanes, or public transit lines, implies increased accessibility in impacted areas. The effect of added capacity, then, can be examined by testing the relationship between accessibility and travel, in particular, trip rates. Note that trip generation analysis, as practiced now typically does not incorporate accessibility measures. Trip production and attraction are assumed to be functions of sociodemographic and land-use variables but not accessibility. Added capacity is not viewed as a factor that causes changes in trip generation. 5

Since accessibility measures will vary wi an urban area, cross-sectional data suffice in the test, longitudinal data, although more

desirable, may not be necessary. This approach is more attractive than the comparison of changes in travel patterns before and after a capacity improvement. The main advantage is the availability of needed data in practically every metropolitan area. There is no need to wait for a capital project in order to obtain before-and-after observations or to establish a control group in order to capture time effects.

Attempts to establish positive links between accessibility and trip generation, however, have not been successful. The most frequently referenced study is by Nakkash and Grecco (1972). Their results exhibit statistically significant effects of accessibility only on school trip production and attraction; accessibility measures are not significant in most trip generation equations. Taken literally, the results lend support to the current practice of trip generation analysis by showing the absence of capacity effects on trip rates with the only exception being school trips. Before drawing any conclusion, however, it is necessary to review the relationship among the key contributing factors of urban trip making.

Ecological Correlations

Urbanization is a result of the benefit of clustering: "To achieve most of the goals that human beings have, "cluster" is more efficient than "scatter" (Smith, 1975, p. 26). Although the preference for isolation may exist, it may be preferable to surrender "isolation or control over space in the interest of conserving transportation resources" (op cit., p.27). This is especially the case for production due to both internal and external economies of scale. Transportation cost, then, explains the intensity of land use, population density, and rent (land value) that decline with the distance from the urban center. Because the city center represents a concentration of opportunities, accessibility in general decreases with the distance from the city center.

The observation that certain levels of residential density is needed for public transit to be viable (Pushkarev and Zupan, 1976) implies that public transit either offers limited service or is not available at all in low density areas. Residents in these areas are then required to have automobiles to gain mobility- This is well supported by empirical observation (e.g., Mogridge, 1986). For data from Portland, OR, and Vancouver, B.C., Shindler and Ferreri(1967) derive bivariate correlation coefficients among the logarithm of net residential density, transit to-auto accessibility ratio, and the number of automobiles per dwelling unit as shown in the table below.

		a.	b.	c.
a.	Net Residential Density (logarithm)	1.000	0.703	-0.691
b.	Accessibility Ratio (transit to auto)		1.000	-0.652
c.	Number of Autos per Dwelling Unit			1.000

Source: Shindler and Ferreri (1967)

It is also well established that auto ownership is most significantly associated with transit use. Shindler and Ferreri (1967) summarized that the relationship between auto ownership and transit use "was so strong, that auto ownership dominated all other factors in explaining the trip-making split between auto and transit travel. Thus, for any given level of auto ownership in an area, transit use was, in a sense, predetermined regardless of the quality of service" (op. cit, p. 24). Additional variables that may enter the picture here are household size and income. These variables are correlated positively with auto ownership and negatively with residential density and accessibility ratio. This may be explained in part by the tendency that households with children prefer single family housings and suburban lifestyles. Thus, an urban area exhibits intricate correlations among variables that are closely related to household travel behavior. These correlations, which

may be called "ecological correlations, " are results of decisions made by households and firms and actions taken by public agencies over time. 6

Effects of Added Capacity

A direct consequence of such strong and clear relationships among residential density, household size, income, and auto ownership, is the multi-collinearity that exists among these variables that have traditionally been considered to most strongly influence household trip generation. Being defined as a function of land use and interzonal travel time variables, accessibility measures are also multi-collinear with the other contributing factors. As a result, it is extremely difficult to determine the independent effect of each contributing factor. 7

Consequently, it has not been possible to produce definitive answers to such seemingly rudimentary questions as: "Does an increase in capacity induce trips?" or "Can we decrease automobile ownership and increase transit use by increasing residential density?"

The problem is further compounded due to the endogeneity of these "explanatory" variables. Although variables representing land use, auto ownership, and accessibility have traditionally been treated as exogenous variables that are determined outside the system, they actually not only feed into each other but also are influenced by travel demand over time. Residential and commercial land use and transportation networks together define accessibility and travel demand. Travel demand and transportation supply characteristics determine the levels of service available on networks. Levels of service, in turn, lead to the enhancement of network characteristics through planning actions, which lead to further residential and commercial land-use development. As this cycle repeats itself over time, it creates an evolving system in which all pertinent variables are endogenously determined within the system. The effect of capacity increase has not been examined in this dynamic context. 8

Summarizing the discussion of this section, economic formulations of trip making offer unambiguous indications that added capacity, which implies decreased cost of travel would lead to more trips and VMT. Furthermore, they have shown that travel time, or monetary budgets, play important roles. Travel budgets, or travel expenditures to be more precise, are clearly determined by households; although no models reviewed here attempt to model the process of determining a travel budget endogenously. The most desirable level of travel expenditure of either time or money will vary from household to household or from situation to situation. The notion of forecasting future travel demand based on the assumption that the travel expenditure of a household remains constant over time is not well founded and appears to produce results that cannot be theoretically supported. Then how does a travel expenditure, or trip making in general, change in response to changes in capacity and resulting changes in generalized travel costs? No definite answer to this question appears to be available. The discussion here pointed out the multi-collinearity among the factors that contribute to trip making, which is a consequence of ecological correlation that prevails in an urban area. In the sections that follow, pieces of empirical evidence are put together to form empirical conclusions on the impact of added capacity.

Impacts of New Highways

The literature on the impacts of new highways appears to be dominated by cost-benefit analyses of highway investment. For example, a sample of articles in Transportation Research Record includes economic impact analyses by Batchelor et al. (1975), Gaegler et al. (1979), and Mahady and Tsitros (1981); articles emphasizing property values as a major element in the cost-benefit analysis by Gamble et al. (1974) and Langley (1976); and articles focusing on community values by Ellis (1968) and Falk (1968). Empirical studies of the impact of new roadways on travel behavior, however, are surprisingly few and far between. 9

A report by U.S. Department of Transportation (1981) concludes:

> It seems clear from the studies which have been conducted over many years that highway service level improvements do induce increases in VMT. However, the magnitude of induced traffic is thought by some to be quite small and, by others, to be significant in certain circumstances (op. cit., p. 22).

On the other hand, Smith and Schoener (1978) maintain:

> A frequent statement advanced by transportation professionals is that highway improvements, by inducing travel, create more congestion they eliminate. Although few data exist to support this statement, it has gained legitimacy by sheer repetition.

This view is repeated in a Research Results Digest issue (Transportation Research Board, 1980).

In this section, available evidence is reviewed to assess the effect of new highways on travel, especially on induced trips.

Taxonomies

Many highways have been built during the periods when urban areas underwent demographic and economic growth. Urban growth has been accompanied by new highways, and new highways were sooner or later surrounded by growing suburbs. In this sense, new highways have been synonymous with urban growth and growing travel demand. The first step in the effort to reveal structural relationships between added capacity and travel demand would be to define different elements of the traffic that seemingly fills up a new highway almost immediately.

Zimmermann et al. (1974) propose that traffic on a (new or capacity-improved) highway be classified into:

- existing traffic,
- development traffic (due to land-use changes),
- natural growth (demographic and socioeconomic changes),
- diverted (from other streets or highways),
- induced (new trips made because of the new highway),
- transferred (from other modes), and shifted (to new destinations).

The last four categories are consequences of a new highway of which induced traffic is a part. Holder and Stover (1972) propose to distinguish between "apparent induced traffic" and "true induced traffic" (read in CSI and JHK, 1979, p. E-1). Similar to Zimmer, et al., Holder and Stover also attribute changes in traffic counts due to "cultural traffic" (due to shifts in demographic or socioeconomic characteristics), converted traffic (from other modes), developed traffic (resulting from land-use change), and diverted traffic (from other streets and highways)" (op. cit. p. E-1). The development traffic and natural growth traffic as defined by Zimme et al., represent increases in trip generation that are accounted for in the land use model that provides input to the trip generation models in the sequential demand forecasting procedure. Similarly, diverted traffic, transferred traffic, and shifted traffic are, in principle, accounted for by the trip distribution, modal split, and network assignment phases of the procedure (although actual practice may be less than ideal (see Harvey [1991], Applied Management and Planning Group [19901). This leaves induced traffic unaccounted for in the sequential demand forecasting procedure. Also unaccounted for is the effect of a new highway on the temporal distribution of traffic, which is not considered in these classification schemes of traffic.

The review of empirical evidence in the literature presented below indicates that new highways do have impact on VMT, presumably due to a large extent to shifted traffic. This impact is well represented by the demand forecasting procedure. The impact of a new facility on induced traffic, however, is not evident.

Impact on VMT

The average trip length appears to increase with the construction of new highways. Voorhees, Bames, and Coleman (1962) cite that the average work trip length in Baltimore increased from 2.6 miles in 1926 to 4 miles in 1946, and to over 5 miles as of the writing of the paper.

Bellomo et al. (1970) also notes similar historical increases in trip lengths. For example, "In Detroit the mean auto driver work trip length in miles increased by 18 percent as the area increased in population by 14 percent, and the average speed of network increased by 12 percent between 1953 and 1965" (op. cit., p. 1). Presumably this is due to a large extent to the geographical and demographic expansion of the area, leading to substantial development and natural growth traffic and, probably to a lesser extent, to shifted traffic.

Voorhees, et al. (1966) offers quantitative indications of the effect of population and network speed on trip length. Based on aggregate data (average trip duration, etc.) from 23 cities, the following model was developed:

$$L = 0.003P0.20S11.49$$

Where:

L = the average trip length in miles.
P = the urban area population.
S = the average network speed in mph (op. cit., p. 31).

The positive effect of network speed on trip length is evident. The effects of the "physical structure of an urban area" on the trip duration and distance are also noted in the study. The distribution of opportunities is not considered in the study.

Accounting for the size and physical structure of an urban area, the network speed, and socioeconomic factors are considered crucial in forecasting future trip length (op. cit., p. 36). Based largely on simulation results, the effects of network speed are summarized as:

> (a) change in the average trip length (miles) for uniform density cities will probably be directly proportional to the square root of changes in network speed; and (b) change in the average trip length (minutes) will probably be inversely proportional to the square root of changes in network speed- experience, however, has shown that peak hour speeds have not greatly changed in large metropolitan areas (op. cit., p. 36).

Then, an addition of capacity, which would lead to a higher highway speed, would also lead to an increase in VMT.

The results reported by Frye (1963) also indicate that a capacity increase has a direct impact on traffic beyond development and natural growth traffic. The opening of the Congress Expressway in a 16 square-mile area in the western suburbs of Chicago led to an increase in the total VMT in the area by 21 percent between 1959 (before opening) and 1961. An increase of 7 percent could be expected in the area due to natural growth. Frye's findings are summarized in U.S.DOT (1981, pp. 20-21) as: "About half the total increase (10.5 percent) was due to diversion of traffic from areas outside the study area. The other 3.5 percent is attributed to induced traffic (i.e., new or longer trips) and adverse travel (the extra VMT generated by travelers going out of their way to use the new facility)...."[10]

Induced Trips

Unlike the other types of traffic on a new highway, induced traffic must be captured in the trip generation phase of the sequential forecasting procedure. Trip generation models typically use demographic and socioeconomic variables for residential trip generation (e.g., household size and auto ownership) and land-use variables (e.g., zonal employment, retail and floor area) for non-residential trip generation. It is not common practice to use variables that represent transportation supply characteristics. In fact, the current practice of trip generation analysis appears to be based on the premise that there exist constant household trip rates that do not change over time, do not vary within or

across metropolitan areas, and are unaffected by the levels of service on transportation networks. Typical examples can be found in the Institute of Transportation Engineers (ITE) trip rates (UE, 1979), "quick response" demand forecasting procedures, and computer program packages (e.g., Sosslau et al., 1978). Contrary empirical evidence does exist. For example, Goulias et al. (1990), in their analysis of 1980 Detroit home interview travel survey results, find that dummy variables representing the county of residence are significant in many of the household trip generation models by purpose estimated in the study. Yet no compelling indicator of trip-inducing effect of added capacity appears to be offered in the studies reviewed below.

As noted earlier, Nakkash and Grecco (1972) present formal statistical tests of the significance of accessibility measures in trip generation equations. They argue, "Conceptually, there is not strong basis for assuming that tripmaking is independent of the transportation system" (op. cit., p. 99). The issue addressed here is precisely that of induced trips in the narrow sense as defined by Zimmermann et al., (1974). If, as economic theory implies, a decrease in the generalized cost of travel leads to an increase in trip making, then households residing in zones with high accessibility would exhibit higher trip rates. Nakkash and Grecco examine this hypothesis by testing the statistical significance of accessibility measures in trip generation models.

The method used is straight forward. A "relative accessibility measure" is defined by trip purpose using destination "mass" terms and friction factors (based on auto travel times, op. cit., p. 102) and normalizing it as follows:

Click HERE for graphic.

This measure is introduced into trip production and attraction models by purpose developed in the Indianapolis Regional Transportation and Development Study (altogether 13 models are defined). The models are estimated with and without stratification which divided the study area into central and non-central areas (the former comprises 105 zones out of the 395 zones in the study area, op. cit., p. 103). The results of this analysis are, unfortunately, inconclusive. Presumably due to the multi-collinearity problem discussed earlier, Nakkash and Grecco report that often "no satisfactory models were developed, " or "models were developed but no statistical testing was possible" (op. cit, p. 107). Only two pairs of trip production models and two pairs of trip attraction models are successfully estimated that can be legitimately used to test the significance of the accessibility measure. Of these, only one production model and one attraction model (both for home-based school trips) offer significant results. (The results are quite counter-intuitive as school trips are of mandatory nature and should be least influenced by accessibility. This may have been caused by the practice of excluding non-motorized trips from trip diaries that were prevalent at the time their data were collected.)

It is entirely possible that trip generation is in fact largely unaffected by accessibility, as suggested by the Nakkash and Grecco study. However, it is also possible that, as noted repeatedly in this paper, multi-collinearity among the explanatory variables may have led to the insignificant accessibility coefficients. The models may have been subject to specification errors; introducing the accessibility measure as a linear additive term may not have been appro-

priate. Accessibility measures are another potential problem. These zonal variables tend exhibit small variations across zones and erroneously represent the true accessibility available to each household. Finally, the aggrega zone-based analysis may have been too insensitive to detect the effect of accessibility.

Kannel and Heathington (1974) examine panel of households interviewed in both 1 and 1971. The same panel of households is u in their 1973 study of the stability in trip generation analysis. The objective of this 1974 study is to examine the hypothesis that "the trip production from households is affected by the accessibility of the household to major activity centers within the urban area" (op. cit., p. 78). The accessibility measures developed by Nakkash (see Nakkash and Grecco, 1972) are used in the study.

Kannel and Heathington use causal models to examine cause-effect relationships among several endogenous variables including accessibility, auto ownership, and mobility. The indicator of mobility is the number of homebased (presumably motorized) trips. Two alternative model structures are examined (each structure is applied to the 1964 and 1971 data and leads to very stable sets of coefficients). In the first structure, accessibility affects both auto ownership and trip generation negatively. In the second model, which is preferred to the first by the authors, the direct link from accessibility to trip generation is eliminated. Thus, accessibility affects mobility, but only indirectly, through automobile ownership.

Smith and Schoener (1978) examine the impact of 1-95 based on "data from origin-destination travel surveys conducted by the Rhode Island Department of Transportation in Providence for 1961 (before construction of 1-95) and 1971 (after I-95)" (op. cit., p. 152). Households are cross-classified according to household size and auto ownership. The dependent variables are VMT per household, vehicle hours of travel (VHT) per household, and auto driver trips per household. Repeated cross-sectional data are used to address these issues. The 1961 sample contains 11, 467 households, but the 1971 sample contains only 855. The study concentrates on vehicular trips; "all trips that were not auto driver trips" were eliminated from the data set (op. cit, p. 154). The study area is divided into two areas: the portion inside the influence of the new highway and the portion outside it.

Smith and Schoener (1978) correctly point out that "Many previous studies have shown that a correlation exists between aggregate highway supply per capita and VKMT per capita. The existence of such a correlation, however, does not guarantee the existence of a causal relationship between the two variables" (op. cit, p. 153). Their analysis based on household data accounts for this problem and offers extremely interesting statistics. They conclude:

> The comparison of the resulting matrices revealed that the highway did not increase trips or VHT, but it did increase VICMT. This allows the tentative conclusion that travelers increase their VKMT until they use up a given amount of travel time. This conclusion supports the standard system-insensitive approach to trip generation as well as the use of travel time as an impedance in trip distribution (op. cit, p. 152).

The study, however, is subject to limitations. First, the sample size for the "after" period is extremely small, probably producing the tendency of accepting null hypotheses of no change. Second, the method used to test the statistical significance of change is less than ideal. Instead of examining the number of significant pairwise statistics in before and after cross-classification tables, the analysis of variance should have been used.

The concurrent processes of the proliferation of automotive transportation and the decline of urban public transit are well documented by aggregate historical data. The impacts of individual highway projects on transit use are less frequently documented. An interesting exception is a study by Richards and Beimbom (1973) which, based on longitudinal transit ridership records before and after the

opening of a highway route, indicates that transit ridership began d g before the highway opening due to residential and commercial relocation, and that opening itself had only limited impact on ridership.

The very question of induced traffic is addressed in NCBRP Project 8-19 (CSI and JHK, 1979 and TRB, 1980). The study is admittedly inconclusive, reflecting the complex nature of trip making, the presence of a wide range of contributing factors, and the resulting difficulties associated with its investigation. Several observations are made in the study. Whether person trips will increase or not is said to depend on the characteristics of the transportation system such as the reduction of off-peak travel times and costs or the level of congestion before the system change (op. cit., p. 2-5). "The increase in person trips produced by a supply increase may or may not result in an increase in the number of vehicle miles traveled, depending upon the nature of the supply change" (op. cit., p. 2-6). VMT may decrease if the supply change decreases the distance between prominent origins and destinations or if it encourages multiple occupancy vehicles.

Importantly, "A congested facility generally reflects the presence of unsatisfied or latent demand for trip making that may be satisfied if travel conditions are improved by the construction of new transportation facilities" (op. cit., p. 2-5). It is noted that non-work trips are more sensitive to supply characteristics, and "the supply change must affect the off-peak travel conditions within the corridor" to have impact on the volume of person trips (op. cit., p. 2-5). These and the number of other observations made in the report suggest difficulties involved in stating the effect of added capacity in general terms. Whether a capacity addition leads to induced trips or not needs to be determined case by case while considering all the supply characteristics and other contributing factors.

Conclusions

Assessing the impact of added capacity is a complex task because of the intricate causal relationships among transportation supply, land use, accessibility, and travel demand. The resulting simultaneity and endogeneity make the use of complex analytical methods inevitable; it is unreasonable to expect that simplistic analyses based on limited data bases will properly address the issue.

At the same time, changes in travel demand are difficult and time consuming to measure precisely. Although carefully designed evaluation studies may offer valuable insights, the case-specific nature of impacts as discussed in CSI and JHK (1979) suggest that generalization of their results may be difficult.

One conclusion to be drawn from this literature review is that only limited utilization has been made of existing travel survey results. Only a few studies have used accessibility measures while no studies have attempted to examine the interaction between land use and travel. It is quite likely that this is due to unavailability of suitable data, despite the many origin/destination surveys.

Traditional origin/destination surveys have been conducted in practically every metropolitan area, quite often at up to three time points that are approximately 10 years apart. Usually metropolitan planning organizations (MPOS) prepare network and land use data that accompany origin-destination trip records. These data files, however, do not seem to be well archived, well documented, or easily available for research purposes. If complete trip, network, and land-use data sets can be made available from selected metropolitan areas of different sizes and densities, they will form a powerful data base that will extend beyond the many limitations discussed in this study. The use of existing origin-destination data appears to be a very cost-effective and an expeditious approach in addressing the added capacity issue. This and other points are itemized in the following tentative summary of this study:

- There is no empirical indication that added capacity generates a significant volume of induced traffic.
- The standard sequential procedure is ca-

pable of forecasting diverted, transferred, and shifted traffic.
- Abbreviated application of the procedure, unwarranted attempts to transfer models, and extrapolation of the models to inapplicable options are unfortunately present.
- A better understanding of trip timing decision is necessary, especially for non-work trips.
- A better understanding of trip chaining behavior is also needed.
- Impacts on auto ownership, residential and job location choice, and land use need to be better understood and incorporated into the forecasting procedure.
- Existing data can be better used with more elaborate statistical methods to test behavioral theories.
- Existing data can be used in multi-regional and multi-period comparative analyses of trip timing decisions, trip chaining behavior, and the issue of suppressed trips.
- Likewise, existing data can be used to examine the effect of

congestion on mode and destination choice. Improving the conventional forecasting procedure can be best achieved through analysis of cross sectional data, because dynamic models derived from longitudinal (especially panel) data may not be compatible with cross-sectional models.

- More widespread use of panel surveys is encouraged.

References

1. Applied management & Planning Group. Traffic Congestion and Capacity Increases. Prepared for Sierra Club Legal Defense Fund, Inc., and Citizens for a Better Environment, 1990.
2. T.J. Batchelor, K.C. Sinha, and A. Chatteriee. Benefit-cost Analysis of the Milwaukee Freeway System. Transportation Research Record, 550, pp. 3547, 1975.
3. M.J. and T.F. Golob. A Critique of Entropy and Gravity in Travel Forecasting. Traffic Flow and Transportation, (G.F. Newell, ed.), American Elsevier, New York, pp. 109-117, 1972.
4. S.J. BeHomo, R.B. Dial, and A.M. Voorhees. Factors, Trends, and Guidelines Related to Trip Length. National Cooperative Highway Research Program Report 89. Highway Research Board, Washington, D.C., 1970.
5. J. Ber and K.A. Small. Modeling Land Use and Transportation: An Interpretive Review for Growth Areas. Environment and Planning A, Vol. 20 No. 10, pp. 12&5-1309, 1988.
6. C.R. Bhat. Toward a Model of Activity Program Generation. Unpublished Ph.D. dissertation, Department of Civil Engineering, Northwestern University, Evanston, IL, 1991.
7. A.J. Bone and M. Wohl. Massachusetts Route 128 Impact Study. Highway Research Board Bulletin, No. 227, pp. 2149, 1959.
8. Cambridge Systematics, Inc. and JHK & Associate. The Relationship of Changes in Urban Highway Supply to Vehicle Miles of Travel. Draft final Report National Cooperative Highway Research Program, Project 8-19, Transportation Research Board, Washington, D.C., March 1979.
9. A. Chuniak and D. Bolger. The Impact of Light Rail Transit on Travel Behavior in Calagary. Transportation Research Record, 992, pp. 8-13.
10. E.A. Deakin. Jobs, Housing, and Transportation:Ibeoryand Evidence on Interactions Between land Use and Transportation. Transportation, Urban Form, and the Environment, Special Report 231, Highway Research Board, Washington, D.C., pp. 25-42, 1991.
11. H.D. Deutschman. Auto Ownership Revisited: A Review of Methods Used in Estimating and Distributing Auto Ownership. Highway Research Record, 205, pp. 3149, 1967.
12. J.D. Downes and P. Emmerson. Do Higher Speeds Increase Travel or Save Time? Transportation and stagnation: challenges for Planning and Research, (P.H.L.Bovyed), Vol. 1, Proceedings of the 10th Transportation Planning Research Colloquium, Colloquium Vervoersplanologisch Speurwerg, Delft, the Netherlands, pp. 171-187, 1983.
13. R.T. Dunphy. Transit Accessibility as a Determinant of Automobile Ownership. Highway Research Record, 472, pp. 63-71, 1972.
14. R.T. Dunphy. The Impact of Metrorail on Trip Making by Nearby Residents: The Van Ness Case Study. Transportation Research Record, 992, pp. 32-37, 1984.
15. S.E.G.Elias, E.S. Neurmmand W.H.Iskander. Impact of People Movers on Travel: Morgantown - A Case Study. Transportation

Research Board, 882, pp. 7-12, 1982.
16. R.H. Ellis. Toward Measurement of the Community Consequences of Urban Freeways. Highway Research Record, 229, pp. 38-52, 1968.
17. E.L. Falk. Measurement of Community Values: The Spokane Experiment. Highway Research Record, 229, pp. 53-64, 1968.
18. C.R. Fleet and S.R. Robertson. Trip Generation in the Transportation Planning Process. Highway Research Record, 240, pp. 11-27, 1968.
19. Frye. Effects of an Expressway on the Distribution of Traffic and Accidents. Highway Research Record, 21, 1963.
20. A.M. Gaegler, J.W. March, and P. Weiner. Dynamic Social and Economic Effects of the Connecticut Turnpike. Transportation Research Record, 716, 28-32, 1979.

21. H.B. Gamble, O.H. Sauerlender, and DJ. Langley. Adverse and Beneficial Effects of Highways on Residential Property Values. Transportation Research Record, 508, pp. 37-48, 1974.
22. G. Giuliano, D.W. Levine, and R.F. Teal. Impact of High Occupancy Vehicle lanes on Carpooling Behavior. Transportation, 17, pp. 159-177, 1990.
23. K.G. Goulias, R.M. Pendyala, and R. Kitamura. Practical Method for the Estimation of Trip Generation and Trip Chaining. Transportation Research Record, 1285, pp. 47-56, 1990.
24. W.S. Homburger. Travel Patterns on a New Regional Rapid Transit System: Clues from the Early Stages of Operations on BART. Transportation Research Record, 563, pp. 38-52, 1976.
25. Institute of Transportation Engineers. Trip Generation. Second edition, ITE Informational Report, 1979.
26. J.F. Kain and G.R. Fauth. The Effects of Urban Structure on Automobile Ownership and Journey to Work Mode Choices. Transportation Research Record, 658, pp. 9-15, 1977.
27. E.J. Kannel and K.W. Heathington. Temporal Stability of Trip Generation Relations. Highway Research Record, 472, pp. 17-27, 1973.
28. E.J. Kannel and K.W. Heathington. Structural Model for Evaluating Urban Travel Relationships. Transportation Research Record, 526, pp. 73-82, 1974.
29. F.S. Koppelman and T.A. Townsend. Task Allocation among Household Members: Theory and Analysis. Paper presented at the Seventh International Conference on Travel Behavior, Aix-en-Provence, France, October 1987.
30. C.J. Langely, Jr. Time-series Effects of a Limited-access Highway on Residential Property Values. Transportation Research Record, 583, pp. 73-82.
31. D. Levitan. Massachusetts Route 128: A Non-emulative Enigma. Transportation Research Record, 583, pp. 45-54, 1976.
32. F.X. Mahady and Washington, D.C. Tsitsos. Economic Impact of I-78 in Allentown, Pennsylvania. Transportation Research Record, 812, pp. 7-8, 1981.
33. J.E. Markowitz. BART Impact Update, Transportation Research Record, 1036, pp. 69-78, 1985.
34. M.C. McCarthy. Multiple-Regression Analysis of Household Trip Generation - A Critique. Highway Research Record, 297, pp. 3143, 1969.
35. M.H. Mogridge. If London Is More Spread Out Than Paris, Why Don't Londoners Travel More Than Parisians? Transportation, 13, pp. 85-104, 1986.
36. T.Z. Nakkash. and W.L. Grecco. Activity-Accessibility Models of Trip Generation. Highway Research Record, 392, pp. 98-110, 1972.
37. S. Narula, M. Harwitz, and B. Lentnek. Where Shall We Shop

Today? A Theory of Multiple Stop, Multiple-Purpose Shopping Trips. Papers of the Regional Science Association, 53, pp. 159173, 1983.

38. J.H. Niedercom and B.V. Bechdolt. An Economic Derivation of the "Gravity Law" of Spatial Interaction. Journal of Regional Science, 9(2), 273-282, 1969.
39. E.I. Pas and A.S. Harvey. Time Use Research and Travel Demand Analysis and Modeling. Paper presented at the Sixth International Conference on Travel Behavior, Quebec City, Quebec, Canada, May, 1991.
40. R.H. Pratt. Impact of Rail Transit on Bus Operations. Transportation Engineering Journal, 97(TEl), February 1971, 3142.
41. B.S. Pushkarev and J.M. Zupan. Where Transit Works: Urban Densities for Public Transportation. Regional Plan News, No. 99, August 1976.
42. C.W. Richards and E.A. Beimbom. Freeway Development Effects Upon Adjacent Transit Usage. Transportation Engineering Journal. 99(TE3), pp. 435-448, August 1973.

43. A.B. Sosslau, A.B. Hassam, M.M. Carter, and G.V. Wickstrom. Quick-Response Urban Travel Estimation Techniques and Transferable Parameters, User's Guide. National Cooperative Highway Research Program Report 187, Transportation Research Board, Washington, D.C., 1978.
44. A.B. Sosslau, A.B. Hassam, M.M. Carter, and G.V. Wickstrom. Travel Estimation Procedures for Quick Response to Urban Policy Issues. National Cooperative Highway Research Program Report 186, Transportation Research Board, Washington, D.C., 1978.
45. R. Shindler and M.G. Ferrari. Auto Ownership as Affected by Transportation System Alternatives. Traffic Engineering, pp. 24-28, October 1967.
46. M.E. Smith and G.E. Schoener. Testing for Significant Induced Trip Making and Travel in Providence, Rhode Island. Transportation Research Record, 673, 152-57, 1978.
47. W.F. Smith. Urban Development: The Process and the Problems. University of California Press, Berkeley, CA. 1975.
48. J. Supemak. Travel-time Budget: A Critique. Transportation Research Record, 879, pp. 15- (references in pp. 27-28), 1982.
49. J. Supemak. Travel Regularities and Their Interpretations: A Discussion Paper. Transportation Research Record, 987, pp. 48-56, 1984.
50. J.C. Thill. Demand in Space and Multipurpose Shopping: A Theoretical Approach. Geographical Analysis, 17, pp. 114-129, 1985.
51. Transportation Research Board. The Vehicle Miles of Travel - Urban Highway Supply Relationship. Research Results Digest, National Cooperative Highway Research Program Digest, 127, p. 7, December 1980.
52. U.S. Department of Transportation. The Costs and Effectiveness of Transportation Control Measures in Achieving Air Quality Goals. Washington, D.C., August 1981.
53. A.I.J.M. Van der Hoorn, W. van Harreveld, J. Vogelaar, and M.J.M. van der Vlist. The Application of Umot in the Netherlands. In P.H.L. Bovy (ed.), Transportation and Stagnation: Challenges for Planning and Research, Vol. 1, Proceedings of the 10th Transportation Planning Colloquium, Colloquium Vervoersplanologisch Speurwerg, Delft, the Netherlands, pp. 155-170.
54. A.M. Voorhees, C.F. Bames, and F.E. Coleman. Traffic Pattern and Land Use Alternatives. Highway Research Board Bulletin, No. 347, pp. 1-9, 1962.

55. A.M. Voorhees, S.J. Bellomo, J.L. Schofer, and D.E. Cleveland. Factors in Work Trip Length. Highway Research Record. 141, 1966.
56. W.M. Webber. The BART Experience - What Have We Learned? Public Interest, No. 45, pp. 79-108, Fall 1976.
57. L. Wesemann, P. Duve, and N. Roach. Comparison of Travel Behavior Before and After the Opening of HOV Lanes in a Suburban Travel Corridor. Transportation Research Record, 12123, pp. 41-52, 1989.
58. M. Wohl. Demand, Cost, Price, and Capacity Relationships Applied to Travel Forecasting. Highway Research Record, 38, pp. 40-54, 1963.
59. Y. Zahavi. Discussion on "Travel-time Budget-. A Critique." Transportation Research Record, 879, pp. 25-57, 1982.
60. Y. Zahavi and J.M. McLynn. Travel Choices under Changing Constraints as Predicted by the UMOT Model. In P.H.L. Bovy (ed.), Transportation and Stagnation: Challenges for Planning and Research, Vol. 1, Proceedings of the 10th Transportation Planning Research Colloquium, Colloquium Vervoersplanologisch Speurwerg, Delft, the Netherlands, pp. 137-154, 1983.
61. Y. Zahavi and J.M. Ryan. Stability of Travel Components Over Time. Transportation Research Record, 750, pp. 19-26, 1980.

62. Y. Zahavi and A. Talvitie. Regularities in Travel Time and Money Expenditures. Transportation Research Record, 750, pp. 13-19, 1980.
63. S. Zimmermann, M. West, and T. Kozlowski. Urban Highways as Traffic Generators. U.S. Department of Transportation, Federal Highway Administration, Urban Planning Division, Washington, D.C., p. 29, August 1974.

Notes

1This is not to say that transportation capacity alone can induce growth in an urban area. The extensive discussions on the subject of transportation investment and urban growth found in the literature (e.g., Bone and Wohl, 1959; Levitan, 1976) suggest that transportation capacity is just one of the factors that jointly contributes to growth and development (Deakin, 1991).

2Perhaps most realistic cases are analyses of the shopping trip frequency and destination choice (e.g., Narula et al., 1983; Thill, 1985). But even they are extremely simplistic.

3This work is said to be the basis of Zahavi's UMOT model system discussed next (Zahavi and McLynn, 1983).

4These approaches do not consider the consolidation of several visits to several destinations into one trip chain (e.g., a trip to work and a trip to shop combined to form a chain of work trip, shopping trip, and home trip), or consolidation of several visits made to the same destination into me visit (e.g., one weekly shopping trip instead of seven daily trips). Another weakness is that no attention is given to how a time or monetary budget for travel is established.

5A notable exception is MTCFCAST, a model system developed for the Metropolitan Transportation Commission (MTC). This model system is discussed later in this paper.

6However, note that ecological correlations are consequences; they are not causes that will lead to changes in the future.

7The approach frequently taken when multi-collinearity is present is to eliminate some of the multi-collinear variables to produce a set of relatively independent explanatory variables. It is not surprising if accessibility measures to be the first to be eliminated because, unlike household size, car ownership, or income, they are aggregate measures defined for traffic zones. As such, they are subject to measurement errors and exhibit smaller variations (see, e.g., McCarthy, 1969; Fleet and Robertson, 1968) and are likely to have less significant coefficients associated with them.

8The problem is even more complex when regional demographic and economic growth is take into account. This leads to another issue of whether transportation capacity leads to regional growth. As noted earlier, the extensive discussions on this subject found in the literature suggest that transportation capacity is just one of the contributing factors.

9A very recent, notable exception is a study of a new ring road in Amsterdam, the Netherlands, to be presented at the forthcoming 1992 TRB Annual Meeting. Unfortunately written documents are not available in time for " presentation.

10The term, "induced traffic, " is used in a broader sense to include both induced and shifted traffic as defined by Zimmermann et al. (1974).

Effects of Added Transportation Capacity on Development

Michael V Dyett, AICP
Blayney, Dyett, Greenburg

Types of Effects on Development

Added transportation capacity, both improvements to the existing system and new facilities and services, may affect the following aspects of urban development:

- Location (distribution effects versus growth-inducing effects -net additions)
- Type (residential versus commercial/industrial)
- Density/intensity(new development versus redevelopment)
- Timing of projects, lease-up and occupancy

How Development Effects Occur

Land use effects traditionally are determined on the basis of changes in accessibility, which in turn affect peak-hour trips, particularly home-based work trips.

Missing Link: Impact of added capacity on latent travel demand, primarily related to discretionary, non-work trips, and the resulting implications for land use and pressures for new development and redevelopment (intensification of use).

In urbanized areas, additional transportation capacity alone may facilitate or promote development, while in urbanizing and new growth areas, whole packages of facilities, including water, sewer and drainage improvements, and schools, are needed.

Setting

Factors affecting the magnitude of development include:

- Land use constraints (geographic, economic, and political)
- Local and regional planning environment (high-regulating versus low-regulating communities)

Dimensions of New Capacity

- Types of improvements (facility and service improvements for existing systems versus additions to the system - new highway and transit capacity)
- Location (central city, older urban areas, urbanizing fringe, free-standing communities)

Strategies for Dealing with Development Impacts

The key is effective, long-range, comprehensive, coordinated land use and transportation planning supported by local political leaders. Transportation improvements as well as private development projects consistent with such plans should not be considered growth inducing and should not be subject to separate impact analysis and mitigation beyond "fairshare" contributions to citywide improvements and specific, off-site improvements not contemplated by the local jurisdiction's comprehensive plan.

When political leadership does not "buy into" such planning, cal solutions rarely are feasible. Moreover, new capacity is likely to have greater growth-inducing effects, especially if other public facilities and services are available to accommodate new development.

In making decisions on whether to add transportation capacity and to approve major development projects, federal, state and local officials should focus on how to resolve conflicts through multi-jurisdictional planning, not

how to solve transportation problems with management, engineering or pricing proposals that they not have political consensus. It also makes sense to distinguish projects that are consistent with comprehensive p and zoning from those requiring plan amendments and rezoning. The decision-making process should include the following steps:

- Design equitable proposals;
- Facilitate constructive negotiation with the community and between affected jurisdictions;
- Make decisions based on plans and packages of improvements, not individual improvement projects which are not correlated with land use plans; and
- Compensate those adversely affected.

Approaches for Studying These impacts

Two sets of research questions are posed; the first is related to general issues of concern about development impacts, while the second focus more specifically on questions related to the development process and the role of added transportation capacity in development decisions.

General Considerations

- If adding capacity in a built area does not noticeably reduce congestion because of latent demand and induced development, why are we doing it? Is it just to increase mobility with related economic benefits? What about mobility for the disadvantaged areas?

- What criteria should be used to evaluate the development impacts of transportation improvement projects in urban areas, recognizing the impossibility of congestion reduction in urban areas over the long term (safety, mobility, land use compatibility, fit with local planning policies and community needs, air quality implications, desire to influence mode split)?
- If level of service standards are correlated with land use, how should through-traffic be evaluated in judging local compliance with these standards? Should different standards be used for the urban core versus the urbanizing fringe of metropolitan areas?
- Recognizing that congestion is needed to get people to change travel habits, does it make sense to use level of service standards for individual transportation and private development projects, or should they be reserved for system and corridor planning?
- Under what conditions can new capacity be added without growth-inducing effects?
- When will new capacity contribute to "economics of agglomeration" or, by contrast, foster more dispersed development?
- How should such development stimuli be incorporated into travel demand modeling?
- When is added capacity really "new" and, therefore, growth inducing? Many proposed projects have been on local and regional plans for years, so effects on new development are difficult to isolate.
- Does it make sense to distinguish improvements oriented to new development, recognizing that trips per capita have been increasing and there is no baseline of unchanging demand? Is the potential for induced travel the same, and what are the resulting land use implications?

Specific Questions Related to Development Process

- How do developers perceive access versus congestion? Although access is more important, does the potential for future congestion affect calculations of project value and internal rate of return, or is congestion considered a cost of doing business that is unlikely to affect project lease up rates?
- Does a proposed congestion management program translate into different, higher capitalization rates for revenue-produc-

ing property? Can these in turn be used to calculate an ability to pay for off-site improvements?

- When do strategies designed to promote jobs/housing be have an impact on trip lengths and other travel characteristics (trip generation, mode split, etc.)?
- What is the duration of development effects attributable to added transportation capacity? Are they short-run in nature, resulting in "one-time" shifts which then diminish as congestion increases, or is the perceived improvement in mobility resulting in a larger commute shed or greater potential retail market of longer-term economic benefit?

Regional Implications:

Modeling Studies in the San Francisco Bay Area

- Build versus no-build scenarios for Metropolitan Transportation Commission
- Implications for land use

Association of Bay Area Governments, Assessing the Future. A Sensitivity Analysis of highway and Road Improvements on Growth in the San Francisco Bay Area, Oakland, April 1991 (Working Paper 91-4).

Institutional, Financial, and Social Impacts of Induced Transportation:
Speculations on the Need for Research

Sheldon M. Edner
Planning Support Branch
Federal Highway Administration

Focus

Additional capacity in a corridor primarily affects the distribution of presumed subsidiary benefits of transportation improvements. While the primary beneficiary may be the transport user, improvements are often justified in terms of their contribution to development (economic and otherwise) or mitigation of transportation related problems (e.g., congestion, air pollution, mobility disadvantage, etc.). These issues are not spatially limited to the corridor, but extend out reciprocally into the broader community in terms of impacts and the acquisition of resources to construct the added capacity. Hence, corridor improvements, both generically and specifically (in terms of adding carrying capacity), tend to shift existing balances in terms of institutional and community goals. Further, they are susceptible to significant environmental (economic, social, technological, etc.) influences because their consequences and benefits are not limited to or based solely on the user.

Key Issues

Changes in spatial accessibility: Who benefits, who loses?

- Region
- Community
- Neighborhood

What is the impact on coalitions that controls decision making and is affected by spatial distributions of benefits?

Who is impacted by plan and project time horizons?

Who controls the horizon?

How should the sub-regional benefit distribution of regional projects be handled?

Flexible versus inflexible systems: adapting to changing metropolitan contexts (intervention of political, economic, technological, and social change)?

Institutional Questions
Impact of overlapping jurisdictional boundaries:
- Integration of general and special purpose governments units
- Role of quasi-government agencies
- Dynamic versus fixed boundaries

Number, kind, and role of institutions:
- Planning processes and decisions
- Operating agency role
- Linking plans and operations

Ripple effects:
- ROW acquisitions and corridor preservation
- Zoning
- Long-term land-use plans
- Utilization of ancillary systems
- Feeder systems
- Employer incentives
- Design standards

Growth boundaries and management:
- Urban versus rural
- Urban, suburban, and exurban

Financial Issues
- Scarce resources
- Time lags in resource commitments
- Relative stake and share
- Political trade-offs in time
- Public versus private goals: costs of alternative financing

Time Horizon: Who and How Far Out Are Plans Made?
- Inconsistent horizons for institutions

Changing the Local Decision Calculus
- What makes a coalition?
- Written and unwritten rules
- Exchange, dependency

Intervening Issues: Differential Consequences of Commitments
- Convention centers
- Jails
- Air quality
- Energy
- Housing

Information and Decisionmaking: Who Knows What Is Going On?.
- Building permits, zoning, plans, and construction
- Big developments
- Construction of complementary systems (e.g., sewers)
- Aggregate impact of multiple small developments

Social Impacts
- Social equality
- Forcing, leading, or following social change

- Meeting the needs of special classes
- Quality of life
- Community size and induced traffic

Synthesis

Additional capacity has been a long-term tradition of corridor improvement as a matter of professional and technical practice. While in some cases it has been extended extraordinarily by political motivation and capacity beyond that necessary to serve, current demand has been validated as a matter of prudent professional judgment. Deciding when it is excessive is a product of multiple factors beyond potential demand. The issue at stake is defining excessive capacity in an era when our social, economic, and institutional capacity is far lower it may have been in the past. The degree to which we can estimate unneeded capacity and develop a planning process capable of incorporating all the necessary factors of excessive capacity is the key contemporary challenge. A supplementary challenge is including new, influential actors in the decision process and anticipating major socioeconomic forces as capacity is added.

Key Questions
- To what extent is the corridor development planning process capable of anticipating all the possible actors that should be included?
- What kind of forecasting should be done to anticipate the influences of economic change, technological forecasting, and social change?
- Should the nature of the Metropolitan Planning Organization process be changed to broaden its membership and focus beyond traditional participants' concerns?
- Does comprehensive and/or land use planning hold the key to mitigating the consequences of additional capacity?
- Should financing be separated institutionally from capacity design and construction?
- Are there better mechanisms for identifying the non-transport, non-spatial benefits of transportation improvements?

Environmental Effects of Added Transportation Capacity

John H. Suhrbier
Principal, Cambridge Systems, Inc.

Summary

The importance of environmental considerations in developing added transportation capacity continues to increase. The preparation of environmental impact statements may have become more routine over the last 20 years as experience with impact analysis methodologies has become more sophisticated. The influence of a wide range of environmental and community concerns on the outcome of actual decisions, though, has both increased and become more complex. This is seen in both the kinds of transportation alternatives that are now being examined and in the additional requirements that are being placed on travel demand forecasting methodologies. In particular, significant attention is being given to travel demand management strategies and to the development of intermodal facilities for the movement of freight and people.

The Clean Air Act Amendments of 1990 (1990 CAAA) represent an

important example of environmental influences on transportation. The requirements of conformity of air quality and transportation plans are receiving considerable attention. However, there are other important analytical implications of the 1990 CAAA. These include the preparation of spatially and temporarily disaggregated emissions inventories; the monitoring of emissions, congestion, vehicle miles traveled (VMT) and vehicle occupancy rates, and the ability to analyze the effectiveness of pricing and other market-based economic incentives. There is a need to improve the interface between transportation and emissions models, especially with respect to the prediction of accurate estimates of vehicle operating speed and acceleration. In addition, trip rather than VMT-based emissions estimates are needed.

Air quality transportation analyses traditionally have focussed on mode choice impacts. Metropolitan areas, however, are increasingly examining a variety of land-use and growth management actions in concert with the development of new or expanded transportation facilities. This is resulting in the need to examine the influence of new transportation infrastructure on the patterns of housing and employment location. In support of these associated analysis requirements, interactive land use/ transportation model systems increasingly are being employed.

There is also a recognition that environmental considerations must be given increased weight in the development of transportation system plans and in the prioritization and programming of individual projects. This is necessary to respond not only to the broader range of policy concerns but also to the increased funding flexibility, strengthened regional decisionmaking, and the desire to address tradeoffs between preservation and increased capacity.

In brief, the attention being given to issues such as congestion management, air quality, downtown revitalization, airport access, and growth management is resulting in a need to enhance current transportation analysis and modeling capabilities. Many short-term improvements are possible, including incorporation of better interactions among the traditional four-step models. More fundamentally, there may be a need for an entire new generation of travel demand model systems. Building upon a geographic information system foundation,

these systems would reflect an expanded range of policy sensitivity, disaggregate or market segment forecasting approaches, and incorporate the influence which added transportation capacity may have on developed patterns.

Use of Travel Forecasting Models to Evaluate the Travel and Environmental Effects of Added Transportation Capacity

Daniel Brand
Charles River Associates

Introduction

While significant additions of highway capacity have slowed in major metropolitan areas over the last two decades, a number of important construction and widening projects are still being considered. However:

> Almost by default, environmental regulations - and the relentless advocates who use them most effectively - have begun to dictate the physical shape and priorities of the region. From the most ambitious bridges to the smallest playground, from airports and highways to shopping malls and boat slips, legal requirements and protests rather planning now orchestrate nearly every decision a builder or government can make (Specter 1991, B1).

The 1990 Clean Air Act Amendments (1990 CAAA) require explicit consideration of whether adding transportation capacity produces more, rather less, air pollution. Indeed, they establish the principle of regional emission budgets and conformity to the emission reduction schedules contained in State Implementation Plans (SIPs). With the important exception of UMTA's Alternatives Analysis cost-effectiveness requirement for major transit investments, the 1990 CAAA requirements appear to be the first significant substantive effectiveness standard by the federal government for new transportation projects.

The principle that travel volumes increase as travel is made easier by adding transportation capacity is well established. More specifically, the conference organizers state:

> The question being increasingly raised is whether adding capacity is producing more, rather less, air pollution. Current transportation practice generally assumes that adding transportation capacity relieves congestion, reduces delay, permits travel at more efficient speeds, and therefore reduces air polluting emissions.
>
> Few (if any) existing trip generation models consider the effects of added capacity to stimulate new travel. The effects of increased trip distance and mode shift may be accommodated by current travel forecasting and growth allocation models.
>
> It is clear however from recent legal proceedings that business as usual for assessing the effects of roadway improvements on air quality will no longer be acceptable. Future air quality assessments will have to determine whether the potential emissions reductions attributable to improve speeds and delay win exceed the additional emissions possibly generated by induced traffic. This poses the possibility that all traditional trip generation models, and perhaps other models as well, may have to be revised. It is critically important to increase understanding of the effects of added capacity on all aspects of travel and to decide if and what improvements to forecasting procedures are necessary in order to accurately assess the air quality effects of added transportation capacity.

The purpose of this presentation is to discuss and recommend improvements to travel forecasting procedures which are required "to accurately assess the air quality effects of added transportation capacity."

Shortcomings of Current Urban Travel Forecasting Models

It would appear that we have come to the end of the era of assuming fixed trip tables, and even fixed loading points, as in the case of the West Side Highway Project (WSHR) travel "models"which assumed no change in Hudson River bridge and tunnel volumes between all WSHR alternatives, including the no build.

Clearly, a fixed amount of travel on a currently congested highway (or highways across a screenline) will result in better air quality as capacity is added. However, it would appear that such analyses are no longer acceptable under the 1990 CAAA, if they ever were.

In general, the shortcomings of today's travel forecasting models in the context of the 1990 CAAA have been known for many years. Twenty years ago, this author wrote:

> Current practice in predicting quantity of travel on transportation networks is based on the theory of equilibrium between supply and demand on the transportation network. That is, there should be an equality between the travel conditions found (such as times and costs) on the loaded network and the travel conditions used as input to the prediction. The current procedure is to model travel behavior as a series of sequential, independent chokes of trip generation, trip distribution, modal split, and c (route) assignment. Land use forecasting precedes travel forecasting as a separate step. For each travel choice, the existing pattern of usage in the region at the prevailing equilibrium between supply and demand is related to a small set (often one) of independent variables. The trend or description is then assumed to hold in the future.
>
> For example, trip distribution is modeled as a function of a simple description of trip lengths that prevailed at the equilibrium between supply and demand represented in the base-date data file. The usual trip-generation procedure relates total trips in and out of a zone only to measures of the activities existing in the zone. The assumption is made that total travel, as measured by trip ends, varies only as development varies, not as conditions on the tested networks change.
>
> In addition, there are computational and logical difficulties in bringing the predicted travel conditions into line with the conditions (if any) used as input to each of the component travel choice models. There is no assurance that travel times and costs resulting from traffic assignment win equal travel times and costs explicitly or implicitly input into each sequentially applied model of component travel choice - that is, that an internally consistent network equilibrium will be produced.
>
> One may reflect that the urban transportation studies in the 1950's and the 1960's took the easy way out by equating usage (a constant) with demand in calibrating models. For existing conditions, the models fit well with usage. Not generally recognized was that present usage is merely a fixed quantity of travel demanded at existing levels of supply, accessibility, and benefits from the opportunities at existing trip ends. The simple trends of descriptions contained in the conventional models cannot be predicted forward with much confidence in a situation as complex as travel wi an urban region.
>
> The shortcomings of the conventional models increase when predictions are made of travel on congested networks (i.e., when small changes in assigned travel volumes result m large changes m link travel times and delays).
>
> Since large-capacity, relatively congestion-free expressways in high-density urban areas are increasingly difficult (if not impossible) to build in the era of urban high-

way controversies, we can look forward to the future equilibrium between supply and demand being quite different from that which existed in the early I%Os when most of our large-scale transportation study data collection took place. Society's changing values introduce new conditions and information requirements in the transportation modeling process.

Operationality in transportation planning today requires demonstrating how smaller transportation systems accommodate smaller amounts of travel and how greater systems accommodate greater amounts of travel. Savings in resources expended by travelers (i.e., user benefits) from transportation improvements must be accurately calculated and vary appropriately with the total resources expended by society to provide those benefits. The latter resources, which are increasingly high valued by society, include air and noise pollution, safety, community disruption and many other effects that are external to the calculation of travel demand in a predictive model. Accurate travel forecasts are needed to calculate their magnitudes.

Only by explaining the causal relations underlying travel demand can accurate forecasts be made of future changes in the performance of a transportation system as land uses and transportation facilities change. Emerging values and information requirements of transportation decision makers require policy-sensitive demand models in transportation planning (Brand 1973, 10-11).

Why New Highways Increase Travel

In theory, any addition of transportation capacity that reduces the times and costs of travel will cause people to consume more travel. Travel decisions involve a series of tradeoffs people make between the times and costs of travel on all available alternatives and the benefits of travel at the trip ends. Figure 1 illustrates the supply/demand mechanism which governs this behavior.

Until now, our experience with changes in travel choice behavior has been derived primarily from travel responses to transportation improvements. These improvements have enlarged the area within which individuals travel to obtain benefits at the trip end. The past few decades in urban transportation have been characterized by high capacity, high speed transportation improvements such as expressways and high capital rail transit systems and extensions. These have made possible travel and settlement on new land which has been incorporated into our metropolitan areas. These investments have also merged and fuzzed the boundaries between suburbia and settlements in rural areas outside the metropolitan areas. Obviously, the effects of these most recent investments in urban transportation are still shaking themselves out

For better or worse, our major transportation investments, which have increased labor productivity and economic development, have sown some of the seeds of their own failure, as is so often the case in our complex economic system. Our success in increasing real incomes in our society through transportation and other economic investments has resulted in increased demand for housing to improve our standard of living. The well-known result of this is that higher real incomes lead our urban populations to move farther out from the center of our cities because there they can consume more housing and land, as well as more travel, at a lower total cost for the entire package. Until now, the added utility of cheaper land, housing, and green grass farther away from our city centers has been greater for our more affluent urban population the added disutility of the transportation cost of traveling to and from their dispersed housing, employment, shopping, etc.

However, we may be faced with a situation where congestion is increasingly out of control in our metropolitan areas. The automobile/highway system is a classic example of a

system characterized by individual choice behavior that puts private interests over the public interest. Every time a person drives a car onto a congested roadway, far more aggregate delay is imposed on others - on the system than on the driver. This aggregate delay on others results in far more air pollution and energy consumption by others by the individual who is causing the delay and pollution. In economic terms, the marginal private cost of highway travel is much less than the marginal social cost of travel on the already congested highway system. In fact, the more congested the highway corridor, the greater the difference between the marginal social and marginal private costs of making a trip by auto (De Corla Souza 1990).

Congestion is a price the system imposes as a result of private decisions to locate in sprawling regions and on larger plots of land, farther away from work and shopping. And as we decide to spend increasing amounts of money on housing, we don't know the transportation price our decisions impose on everyone else. We invest heavily in expensive housing without confronting the total cost of our location decisions. This leads to real inefficiencies; the system has lost its ability to confront consumers with the real costs of their decisions. This is as true in the long-run for our land use location decisions that generate congestion as it is in the short-run for our individual travel decisions.

There are reasons that new transportation investments accompanied by better information for travelers can result in less congestion and added travel without features (Brand 1992). However, in general, except for some very special circumstances, new transportation capacity that makes travel "easier" will increase travel. The question remains: will the increased travel result in increased air pollution?

The Role of Forecasting Models in Evaluating Air Quality

Clearly, improved travel forecasting models are available and wi the state of the art to accurately assess the air quality effects of added transportation capacity. No one should doubt that improved forecasting models are the principal way to address this question. Since travel in a metropolitan area is influenced by many factors which change at the same time, direct observation of the effects of changes in individual causal variables that may affect the dependent variables of interest (i.e, travel and air pollution)is necessary. The problem is to specify and structure these models properly.

Planners should be aware that the travel forecasting techniques used in transportation planning for the last 30 years have their own implicit rules of behavior. Behavior rules include not only those implied by the independent variables included (and correlations between these and variables not included: the unobserved attributes); the changes described by the data (e.g, behavior on new versus developed land, direction of change, cross-sectional versus time series data); and the estimated coefficients with their assumptions on the distributions of tastes in the population; but behavior rules also include those on the structure of the travel choices (e.g., the sequence of choices) and choice alternatives (e.g., alternative destinations) over which the models are applied. A better and broader understanding of the rules of behavior embedded in current travel forecasting ques(e g., trip generation equations, gravity and logit models) is needed among planners. A full understanding of the choice structure implied by the models being used can help in using models efficiently and in selecting appropriate forecasting models. Lack of knowledge of a model's implied choke behavior may lead to grievous errors in its application. Examples of such problems with existing models and their consequences will be given m the presentation.

Specific Recommendations

Ultimately, an accurate assessment of the air quality effects of adding transportation capacity can be made only with travel models which are properly embedded in the long run -general equilibrium models that explain how land use and travel vary simultaneously with added transportation capacity. Only these models can control for (hold constant) all the other factors that affect travel (assuming they have been estimated properly).

Such ultimate general equilibrium models may seem like too tall an order - too far to reach - even in this national conference. However, we need look no farther the last large research project to investigate the relationship between transportation supply and added travel to realize our problem:

> Although the researchers have concluded that there is a highway supply relationship, this relationship is not direct. A complex causal change exists: highway supply changes bring about travel time and cost (level-of-service) changes, which, in turn, effect travel pattern changes. In the short-run, travel patterns and levels of service interact, resulting in an equilibrium. In the long run, the short run changes (with many other factors) influence future land use patterns. These land uses influence travel patterns, which must again reach an equilibrium by interacting with highway levels of service. In both the short run and the long run, VMT levels exist as one of many aggregate measures of the impacts of the highway supply changes.
>
> The complexity of this causal linkage between highway supply and VMT has two important consequences: first, the direction of VMT changes because a given highway supply change can vary; second, there are many variables that affect both the direction and the magnitude of VMT changes (NCHRP 1980, 2).

This research project attempted to measure the VMT impacts of two major highway additions in the San Francisco region - with inconclusive results. The research was never formally published.

The first recommendation, therefore, is to carry out further research in this area, including the development of land use or general equilibrium models. These would enable the prediction of land use and travel simultaneously as these are determined by a given transportation system - improved over today's - and by the many other determining factors which will be described at this conference.

The second recommendation is that we should be forecasting travel in urban areas, not with trip generation equations that are insensitive to travel conditions (as per the shortcomings of current forecasting models cited above), but with direct demand models which are valid descriptions of travel demand, given a fixed land use distribution (Domencich 1968, 64). Direct demand models forecast travel directly by mode between origins and destinations (perhaps, even by time of day) as a function of the activity systems at the origins and destinations. The price and service conditions are forecast by the mode and all its substitutes.

Direct demand models are themselves simplifications of the general model. They are partial equilibrium models which describe how part of the system behaves in order for it to be in equilibrium with the rest of the system Thus, we model the behavior of the trip-maker who considers all trip-end opportunities fixed. This doesn't necessarily mean that this separation is at fault It only means that:

- The long-run models must be structurally valid, and
- The short-run models should incorporate relations among travel and its determinants that are expected to remain valid in the future.

Examples of how the current, sequentially applied travel models (e.g., trip generation, distribution, etc.) violate the second condition were given above under "Shortcomings."

Regardless of whether they describe full or partial equilibria, the air quality forecasting

travel models must also contain appropriate supply/demand equilibration mechanisms that measure that the changes in travel times and other measures of system performance that give rise to travel (as input to the model) are the same as those produced by the model. This congestion sensitivity is the only way to test the assumption we generally make today "that adding transportation capacity relieves congestion, reduces delay, permits travel at more efficient speeds, and therefore reduces air polluting emissions."

The third and final recommendation is that we need considerable research and development of improved (structural) travel demand models which are sensitive to the great number of "non-traditional- transportation improvements called for under the 1990 CAAA. Specifically, Section 108(f) of the 1990 CAAA lists and describes 16 transportation control measures (TCMS) which have been described in an EPA guidance (EPA 1991). Since these TCMS, in many cases, involve constraining highway travel, we know very little of their effects on travel. Considerable travel modeling work in this area is needed to be able to forecast the contribution of these TCMs to meeting the air quality objectives of our SIPS.

Click HERE for graphic.

References

Brand, Daniel. "Intelligent vehicle highway systems: A smart choice for travelers and society." TR News, p. 160, May/June 1992.

"Theory and method in land use and travel forecasting." TRB Record 422, pp. 10-11, 1973. DeCorla-Souza, Patrick.

"Suburban/urban transportation investment: What will it cost and how will I pay?" U.S. Federal Highway Administration, 1990.
Domencich, Thomas A., Gerald Kraft, and jean-Paul Valette.

"Estimation of urban passenger travel behavior: An economic demand model." Highway Research Record 238. p. 64, 1968.

NCHRP Staff Digest of Project 8-19. "The vehicle miles of travel: Urban highway supply relationship."

Cambridge Systematics and JHK & Associates, p. 2, December 1980.
Specter, Michael. "Environmental rules: How they dictate region's agenda." The New York Times. p. B1, November 25, 1991.

U.S. Environmental Protection Agency, Office of Mobile Sources. Transportation control measure information documents (Draft), by Cambridge Systematics, Inc. et al. Ann Arbor, MI. October 1991.

Travel and Locational Impacts of Added Transportation Capacity Experimental Designs

Peter Stopher
Director, Louisiana Transportation Research Center and Professor of Civil Engineering, Louisiana State University

Introduction

The purpose of this paper is to explore experimental designs for measuring the travel effects of adding transportation capacity, particularly to a congested transportation system. Theory had deduced that nine potential effects may arise when capacity is added to a congested travel corridor (Stopher, 1992; Harvey and Deakin, 1991). Briefly, these effects or impacts are:

- Route changes
- Mode changes
- Trip timing changes
- Destination changes
- Trip frequency/trip chaining changes
- Auto ownership changes
- Residential location changes
- Employment location changes
- Regional growth changes in either or both population and employment

It is important to distinguish that the first five of these are likely to be short- to medium term changes, taking place anywhere from the day of opening of the new capacity to sometime probably within the first one to two years from the capacity addition. On the other hand, the latter four changes are likely to be medium- to longterm, with most effects showing up at least one or two years after capacity addition and up to maybe ten years or more later. This means that the first five changes may be comparatively easy to measure in relation to either an actual capacity addition or a description of a possible capacity addition, while the latter four are likely to be comparatively difficult to measure. The measurement difficulties for the longterm changes will arise in large part from the fact that, as more time passes, other events and changes quite distinct from the capacity addition will cause changes in each of auto ownership, employment and residence locations, and overall regional growth. These will include family life-cycle changes; cyclical changes in the local, regional, and national economies; new technologies; changing values; and both manmade and natural disasters.

One might also argue that if it is necessary to spend ten or more years to determine if certain of these effects take place and ascertain their magnitude, this may be much too late to impact the investment decisions being made in the next several years. Such an argument suggests a redundancy m measuring long-term effects of this nature. This author would, however, disagree with such a notion, in that the then - current problems, the nature of which is as yet uncertain, may well be a result of actions taken in years preceding, so that such a longterm study will illuminate much in the causality of transportation problems. Therefore, this paper will consider the potential to measure even quite long-term effects, even if a decade or more is required for measurement The issues to be addressed are much more concerned with how to account for the time-dependent aspects of the externalities than with the total length of time, per se, that may be required for measurement.

Two additional context issues are important to consider. Stopher (1992) has argued that most of the effects of added capacity that are the focus of this paper will occur in urban areas or major corridors of urban areas that experience congestion that is significant in both duration and geographic extent. Thus, in a system that is largely un congested except for a specific capacity-related bottleneck, most of the effects are unlikely to occur or are likely to be very small in magnitude. Second, much of the theory and anecdotal information that supports the contentions that capacity increases cause the array of effects described earlier in this introduction, maintains that the effects are substantially more significant in larger urban areas than in smaller ones (Remak and Rosenbloom, 1976).

Thus, any experimental design should preferably be focused on larger urban areas (perhaps those with at least 1 million population) and also on those where congestion is fairly widespread in time and along at least two or more significant transportation corridors. However, to the extent that resources may allow, it would be of considerable value to perform the experiments in several locations (at least four), so that variability in size and extent of congestion could be included. The minimum of four locations is suggested on the grounds that:

- Two points always lie on a straight line, so that no significant conclusion could be drawn from two locations and
- While four points are still inadequate for statistical significance, they allow sufficient variability to determine if effects may be postulated to vary with either population or extent of congestion.

It is also appropriate to note here that measurement of the types of changes theoretically expected as a result of capacity increases may be done without any such capacity increases being undertaken. The arguments that define the impacts of capacity increases are mirror-image arguments about how people re-- ac-t-to increasing levels of congestion. If one is willing to assume that this reversibility principle holds, then it is possible to measure the context of increasing congestion and how people respond to it. Thus, if nearer destinations are substituted for farther ones, trips become chained or rescheduled, people shift from using the car to using public transit, and, in the longer run, auto ownership is decreased; and home or workplace is relocated to reduce the travel time involved in commuting. It may be concluded, then, that each of these changes is potentially reversed when a capacity increase is provided. This notion is used in considering the experimental designs that follow.

This section elaborates on the experimental design that would result from the comprehensive strategy. The next section outlines three possible generic approaches to the experimental design. The following three sections take each of these experimental designs, elaborate on them, and review the pros and cons of each. The sixth section of the paper suggests a comprehensive strategy that combines elements of each of the three approaches. This section elaborates on the experimental design that would result from the comprehensive strategy. The final section draws conclusions that represent initial possible recommendations on the experimental design that could be implemented.

The paper is intended to be a resource document that will provoke new thinking and discussion. Therefore, it is not intended to be exhaustive on possible experimental designs but, instead, to deal in depth with three different designs that may help illuminate both the opportunities and the problems. It is the author's hope that three designs and the comprehensive strategy will serve to set others thinking and may produce yet other, more effective designs.

Review of Approaches

Three categories of experimental approach are considered in this paper. Each approach has certain strengths as well as certain weaknesses as many as possible of which should be explored. A combination of approaches may offer the strongest experimental design because of

the ability of such a strategy to offset weaknesses of the individual approaches, and also to offer some instances of two or more ways to measure the saran effect. Three approaches considered in this paper are:

- The case study
- Attitudinal and preferential surveys
- Longitudinal panel surveys

In the remainder of this section, a brief description of each approach is provided. The following sections then explore the strengths and weaknesses of each.

The Case Study

The case study involves selecting a corridor in which a capacity expansion is to be provided. The approach would involve a before study to determine travel patterns in the currently congested corridor, followed by a series of after studies spanning several years to obtain data on changes arising from the capacity-expansion project. The samples for the before and after surveys would be drawn not only from the immediate vicinity of the project, but also from a larger study area wi the potential influence area of the project. Surveys would most likely be conducted on both residents and businesses within the total study area. The surveys would be expected to report on revealed preference for residents and businesses alike, i.e., providing data on what people and employers currently do in relation to choices involving each of the issues of concern in capacity expansion and congestion.

Attitudinal and Preferential Surveys

With the attitudinal and preferential approach, a number of distinct surveys can be included. The approach can be used without an actual capacity expansion project, although use in conjunction with a project may be desirable. Among the included surveys are focus groups, attitudinal surveys of both residents and employers, and stated preference surveys of residents and employers.

Focus groups could be conducted with groups of residents and employers to determine the extent to which congestion impacts their choices relating to destinations, modes, time of day, location, auto ownership, etc, and whether or not such choices are potentially affected by a change in the congestion levels as would occur when capacity is added. Building on the results of such focus groups, attitudinal surveys could be designed that would measure congestion and capacity-increase impacts on travel, location, and auto ownership on psychological scales of importance, propensity to change, etc. A more quantified approach would result from designing stated-preference surveys of residents and employers, based on the focus groups, and offering the standard types of trade-off questions in a stated-preference design. Such a survey could be conducted in a variety of locations and at different times to produce a more extensive array of responses on congestion and capacity-increase effects.

Longitudinal Panel Surveys

A longitudinal panel survey would be undertaken in at least one of two ways: either an actual capacity-increasing project situation in which the panel is initiated prior to the project and continued for several years after; or using a selection of areas where congestion is changing and determining how panel behavior or attitudes and preferences change over time as congestion also changes. An important aspect of a longitudinal panel is that it would, in this case, follow residents and employers who move away from the location where they were when the panel was initiated. This would be important as a means to determine the extent to which relocation solved the problems arising from congestion.

Panel surveys could use either revealed preference measures, stated preference measures, attitudes, or a combination of any or all of these methods. Revealed preferences would be more instructive in panel surveys compared to

one-shot surveys, because of the ability to measure the dynamics of prior changes.

The Case Study Approach

The case study approach involves identifying a location where a capacity-increasing project is to be constructed and conducting at least one before survey, followed by a series of after surveys. The surveys would be directed at both residents and employers to determine the extent to which the congestion existing prior to the capacity addition has impacted specific decisions relating to travel, activities, and location; and then to measure how the relief of that congestion impacts those same decisions subsequently. The notion of a case study is clearly to rely, to as great an extent as possible, on the measurement of revealed preferences. In other words, the issue is to determine the actual behavior before the project and then to measure changes in behavior after the project.

At first glance, this approach appears to be the most obvious and sensible one to measure the effects of a capacity increase. However, once actual design issues are confronted, it becomes much less apparent that this is a workable approach. The first issue to be dealt with is the definition of the populations of residents and employers from which the sample should be drawn. If the population is defined as those residents and employers who are located within the corridor of the project, even where the corridor is defined quite broadly, this will lead to inclusion of a number of residents and employers who will not be affected by the project. At the same time, there may be many residents and employers who would not be included in any definition of the transportation corridor who are impacted considerably by the project.

The second issue is that the before sample should be drawn so as to include residents and employers who may not use the transportation corridor before the capacity increase (because congestion has made opportunities reachable through that corridor too unattractive to be considered), but who will use the corridor after the project is completed. If the contention holds that capacity increases in the transportation system lead to the relocation of homes and workplaces, then there is a third group that cannot be captured in the before survey, representing those who move into the corridor subsequent to construction of the capacity increase.

None of these sampling issues is completely insurmountable. As is discussed in more detail later in the paper, some combination of cross-sectional and panel surveys might serve to resolve some of these problems. Nevertheless, very significant sampling issues remain, particularly in defining the extent of the geographic area from which to sample, the means to identify in the before survey those who will be affected after construction, and the potential implications for random sampling that some very large samples may be required in Order to include a significant number of those who exhibit impacts from the project.

The next issue relates to the time frame of measurement. As has already been noted, a number of the impacts that are theorized to occur are of long-term impact. This implies that measurement should continue for several years in the after period. The problem presented by this is that of externalities. it is unlikely that the residents and employers in the project area will be unaffected by any other transportation System changes over the several years that measurements should take place. However, determining which impacts follow from the construction of new capacity and which follow from the variety of other transportation system changes taking place is likely to prove extremely challenging. Consider the case of the construction of the Century Freeway in Los Angeles, for example. Assuming one can surmount the sampling problems to select an adequate sample for the before and the series Of after surveys, within one or two years of the opening Of the freeway, it can be expected that the light rail facility along the freeway median will commence operation. There is also a plan to add other rail projects in the vicinity of the freeway, such as the Coast Light Rail Line, extensions of Metro Rail to the confluence of the Century and

Santa Ana freeways, and the potential addition of HOV lanes to several freeways in the area. While all this proceeds, it is surely improbable that automobile fuel prices will remain unchanged, or that transit fares will remain fixed. Other changes, such as new technologies for the automobile, response to clean air legislation, and the like will all impact travel behaviors and location in some form or another. The challenge will be to control for these externalities in order to have a clear measurement of precisely how the capacity addition, represented by the new freeway, had an impact on travel patterns and household and employer decisions in the years following its opening.

Finally, the case study approach relies on the measurement of change. The issue here is that change must be measured relative to something. In actuality the question being addressed by the experimental design is to determine changes that take place as a result of the addition of capacity, which implicitly mean changes that are different from those that should have occurred without the change in capacity. This raises the real nub of the case study approach. There is no question in this author's mind that the various surveys that could be conducted on a case study of capacity increase will measure change in travel behavior: travel behavior is highly dynamic and results in continual changes. The issue is to determine that changes have taken place that are different from or greater those occurring without the capacity increase. Further, if the contention made by several recent papers that peak period travel seems to continue to increase, despite increasing congestion (Fleet and DeCorla-Souza, 1991), the issue becomes one of determining how behavior would have changed without the project, and comparing that to the changes that occur with the project.

This issue of the relativity of change suggests that the requirement would be to find a similar transportation corridor in which no capacity increase is planned, but where congestion levels are identical in the before period. Next, a panel study would be conducted to determine the changes that occur in that corridor. The impacts of the capacity increase are then measured by the differences between the two study areas. It is beyond the scope of this paper to define the measures of similarity that must be used to select the null corridor, but this is clearly a significant challenge in itself.

In considering this approach, one is reminded of the studies that took place in the 1970's, in particular, that endeavored to measure the impacts of transportation on land use (the Lindenwold Line and others - Boyce, 1970, Demetsky and Shepard, 1972 inter alia). These also took place in a case study context and seemed to be universally unable to substantiate the actual extent of changes caused to land uses by the addition of new transportation capacity. Issues such as the impacts of uncontrollable externalities and isolation of a control location against which to measure change were among the principal reasons behind the failure of these efforts to measure, with any degree of certainty, the impacts of transportation facilities on land use. In the debate on what impacts capacity increases in the highway system have on travel patterns, locational decisions, and growth, those maintaining that many of these impacts do not occur rely on these failed studies on land use to support that position. In actuality, the studies did not establish the lack of a linkage between land use and transportation but simply failed to find it because of the measurement and experimental design problems. This should emphasize the need for care in designing experiments for the capacity-increase issue.

Attitudinal and Preferential Surveys

The difficulties alluded to for the case study approach give rise to the idea that other methods need to be examined as offering a potential alternative in which uncontrollable externalities, control situations, and sampling difficulties might have less impact. As noted earlier in this paper, attitudinal and preference approaches include a number of measurement methods and procedures, including focus groups, attitude surveys, and stated preference measurement In this Section, each Of these broad categories is considered further in terms of what can be measured and in what situations, to determine if they offer alternative methods to the experimental design of the case study approach.

Focus Groups

Focus groups do not provide a means to measure the impacts of capacity increases. However, they do provide a means to determine what decisions people believe are impacted by congestion or by an increase in capacity and should be a precursor to any field study of impacts. In this case, the experimental design would be based on selecting several groups of people to participate in independent focus groups, considering the issues of congestion and congestion relief. Focus groups could be drawn from various different categories of workers (e.g., by income, auto ownership, etc.), different family groups (to determine interaction between family members' decisions), and employers with varying employee types.

Each focus group would be asked to consider the issue of the way in which congestion impacts what they do and how they organize their lives. They would be asked to consider how they would react to continued increases in congestion levels and then how they would react to the provision of new capacity in a congested corridor. Such focus groups would serve to provide an initial test of hypotheses about the impacts of capacity increases and would also provide detail on the specific "s of decisions that are impacted. They would be the precursor to any of the other attitudinal and preference measurement methods discussed in this section.

Three advantages stem from the focus groups. They are independent of externalities, since the nature of the focus group is to focus on the specific set of issues of concern. Second, they need neither an actual capacity-increasing project nor a control corridor in which measurements would be taken. Indeed, they offer the potential to draw similar focus groups from congested urban areas across the nation and thereby determine, further, if there might be regional or other differences in response to congestion and capacity increases that have not been hypothesized to date. Third, there are far less serious difficulties in selecting the sample for inclusion in the focus groups, since the area of influence of a specific project does not need to be defined. A potential qualification for inclusion in the focus group may only be to establish that the individual experiences congested traffic on reasonably frequent occasions, either on work trips or on non-work trips. It is dearly advantageous to determining the full set of impacts to include those who experience congestion on trips other than commute trips in order to determine a broader range of responses to congestion and to potential capacity-increasing projects.

Attitude Surveys

Using the results of focus groups, attitude surveys could be designed to measure, on psychological scales, aspects of response to congestion and capacity increases that would result in an initial decrease in congestion. Attitudinal surveys can be constructed to measure such constructs as importance, preference, likelihood to change a behavior, and satisfaction, inter alia. Such surveys can be conducted on residents and employers, under conditions of a case study, or under hypothetical circumstances. The focus groups would also be likely to provide information on the pertinent descriptors of congestion and capacity increases.

Because there is generally a fairly high degree of unreliability in both reporting behavioral intentions and longer-term responses to hypothetical (or even actual) events, the attitude surveys would be most likely to measure the short-term responses by residents to increasing or decreasing congestion. Attitude surveys, however, may be successful at determining likely longer-term responses by employers, particularly because senior manage-

ment of a company is more accustomed to considering longer-term responses and actions required by the company. Experience in interviewing employers in connection with Regulation XV in the South Coast Air Basin of California showed a relatively high level of responsiveness on the potential of increasing congestion to generate changes in the way in which companies do business and their choice of location.

As with focus groups, one of the primary benefits of the attitudinal measures is that they do not require a case study or the identification of a control transportation corridors The primary disadvantage of such an approach is the limitations on what can be measured and the reliability of measurement. Potentially, such techniques may have their greatest pay-offs in use with senior managers of employers in congested areas where both short- and long-term responses may be obtained more reliably. The sampling benefits mentioned for focus groups apply also to attitudinal measurement techniques.

Stated Preference Surveys

The third type of survey under this general heading, and the one that probably has the greatest contribution to the travel behavior of individuals, is that of stated preferences. In a stated preference survey, individuals are presented with a series of trade-offs between attributes of alternatives that they may consider choosing and are asked to indicate when attribute changes would precipitate a change in current behavior to an alternative behavior. The key to an effective stated preference survey is to design a composite set of trade-offs that allow reliable measurement of potential behavior changes in response to a particular type of event or system.

Stated preference surveys are becoming the accepted method for measuring likely ridership of new technologies, such as very high speed ground transportation, and have also been used successfully by researchers in Europe attempting to obtain improved measurement of value of tin-se and value of certain types of accidents. The application of the technique to congestion and capacity increases seems obvious, therefore.

The design of the stated preference survey would again benefit substantially from the focus groups, which should be considered as a precursor for the design. In this case, the focus groups would not only provide information about the attributes to be used in the preference measurement but would also provide inputs on the description of the environment and the ranges of values of attributes to use in the stated preference designs.

Given uses that have been made of stated preference measurement to date, it is not clear how reliably it will measure longer-term changes in response to capacity increases. However, there is clearly no difficulty in including such options as changing vehicle ownership and changing home or workplace location as part of the instrument. Unlike revealed preference measurement, it is not necessary for the study to span the time period within which such longer-term changes will be made in order to determine the likely behavior changes that may occur. Conducting the survey over two or three years, in which changes in the actual transportation system experienced by subjects of the survey is tracked, would provide increased information on the reliability of the method.

As with each of the methods described in this section, there is no requirement for a specific case study of capacity increase nor a control corridor; and externalities are controlled through the questioning mechanism. There are also no more complex sampling issues those already noted for selecting members for the focus groups. The measurement issues in this case revolve around defining an adequate set of trade-off situations to measure behavior changes that might follow from a capacity increase in congested transportation corridors and to define behavior changes likely under worsening congestion. In addition, the stated preference method is fairly extensive in questioning and may be less well-adapted to use

with senior managers of employers but will find its strongest application with residents.

Longitudinal Panel Surveys

While not necessarily a distinct methodology from the preceding ones, the specific element of a longitudinal panel survey of interest in this paper is its capability to measure change more reliably any other survey methodology. In a panel survey the underlying principle is to recruit a generally small panel of individuals that may be drawn to represent different subgroups of the population of interest and to survey the panels repeatedly over a period of time. Issues that arise in the execution of panel surveys include replacement of panel members that leave the panel and sampling issues relating to the initial recruitment of the panel.

By the nature of the panel principle, which is the measurement of change, the likely method of measurement is that of revealed preferences. In other words, the panel members would be asked to report on actual behaviors at each time of survey, from which changes could be determined over time. While measurement of stated preferences or attitudinal data could be included in a panel survey, the change measured in this case would be the stability of the preferences, not the response to actual changes in the transportation system. Therefore, the panel should be considered first and foremost as a revealed preference tool.

A longitudinal panel could be used in two different ways to measure the impacts of either congestion increases or capacity additions designed to relieve congestion. First, a longitudinal panel could be set up within the context of an actual capacity-increasing project in a congested area. The advantages of the panel are obvious compared to the execution of a series of cross-sectional (i.e., independently-sampled) surveys. In this case, the panel would be recruited prior to the new capacity opening and would be asked to report on actual behaviors for a period of time, showing travel patterns under conditions of congestion. After the capacity increase has been completed, the panel would be surveyed on a number of successive occasions to measure changes in travel patterns and also to determine if changes take place in auto ownership, workplace location, or home location.

Unlike many panels conceived for transportation purposes, it would be important in this application to continue to include members of the panel who move, in order to track possible trade-offs in transportation service that were achieved through the relocation, and to offer some potential to include control measures through panel members that move to a relatively uncongested location.

This application of a longitudinal panel, however, does not resolve the issue of relating the amounts of change to what would have occurred without the capacity-increasing project. Therefore, the requirement will remain for subgroups of the panel to be set up in locations that have similar congestion levels in the before time frame and no capacity-increasing project in the after period. Further, there would need to be similarity in the panel members with respect to a variety of demographic and travel orientation characteristics in order to measure the change caused by the capacity increasing project. In effect, there would need to be a pairing of panel members, with each panel member in the case study location having a counterpart with very similar characteristics in a location where there is no capacity-increasing project and a similar level of congestion. Such a sample design, while not impossible to achieve, will certainly be extremely time-consuming and expensive to set up.

The second potential use of the longitudinal panel would rely on the reversibility notion of the changes resulting from capacity increases. Rather than being set up in a case study context where a capacity increasing project was to be constructed, this application would simply measure changes taking place as congestion worsens. Although this application would still require a control location against which to measure how much of the change resulted from increasing congestion, it may be possible to

conduct this study effectively by choosing several locations in which congestion exists at the outset of the study at very different intensities. For example, one subsample for the panel might be selected from an urban area in which congestion is short-lived and geographically restricted, and where the urbanized area is not experiencing significant growth. At the other extreme., a subsample might be located in an area where congestion is widespread, lasts for many hours, and the urbanized area is experiencing rapid growth. Additional subsamples may be located in areas that lie between these two extremes.

Panel subsamples would be required to match well on demographic and travel characteristics, within the limits offered by the varying types of urban areas. However, , the sampling would not need to be inclusive of all possible groups that might be affected by congestion or capacity increases. Rather, the panels could be restricted to two or three primary demographic subgroups. If consistent results were obtained from each of the selected sub-groups, generalizability to the entire population would be feasible.

In both applications of the panel survey, there would be a need to include within the study design a comprehensive monitoring of the transportation supply and costs in the vicinity of the panel members. This would be required in order to ascertain the extent to which congestion changes during the study and to provide the needed basis for correlating congestion levels with travel behavior changes. In addition, , it would provide at least a measurement of potential externalities that may affect the overall measurement of congestion-related changes.

The panel survey will most likely apply to measurement of those impacts affecting residents. A panel survey of employers may be an interesting proposition but may not find acceptability within the target population. Therefore, the most probable application of this method is to residents of selected urbanized areas.

A Comprehensive Strategy

So far, this paper has considered three distinct approaches to the experimental design for measuring the impacts of capacity increases on travel and location. As has been mentioned several times, however, these three approaches are not mutually exclusive. A real potential exists to combine elements of all three approaches to produce a better experimental design, a design that may overcome a number of the shortcomings that have been identified for each approach alone.

A comprehensive strategy should start out with the use of focus groups. The focus groups should target several different groups of residents, including those who work outside the home and those who do not, and should also include one or more groups of employer representatives. The focus groups would serve to illuminate the specific elements of congestion and capacity increases that may affect travel, locational, and related behaviors and will also provide some insights on the attributes of congestion and capacity increase to which people respond (e.g., time spent in stop-and-go traffic, total travel time, unreliability and instability of traffic flows, etc.). The focus group findings would be used in the design of subsequent survey instruments, as well as the sample design, itself.

A combination of revealed and stated preference measurement will provide the richness of data to identify what the impacts are and by what magnitude these impacts cause changes in travel decisions, locational decisions, and related decisions such as vehicle ownership. The particular appeal of stated preference measurement is that it can be conducted with or without an actual capacity-increasing project, and the externalities can be controlled. On the other hand, revealed preferences are the only true measures of the actual behavior changes that take place. Therefore, some measurement of revealed preference is necessary to validate the stated preference data and to test the hypothesis that the changes indicated by stated preference and focus groups actually do take

Click HERE for graphic.

place. In both cases, what to measure and in what units to measure will be enhanced considerably by the results of the focus groups.

Among the more difficult issues raised in considering the case study approach were selecting a sample, identifying who is impacted by a specific project, and finding a parallel control location in order to determine the amount of change likely to take place without the capacity-increasing project. The combination of revealed and stated preference methods offers a potential to avoid each of these problems. The presence of a capacity-increasing project is not necessary, although it could be used in one or more instances if such a project were available. The survey would be designed so that the stated preference portion would question respondents about their responses to both worsening congestion and alleviating congestion through a capacity-increasing project. In the event that none of the selected locations had a capacity-increasing project, validation of the stated preference findings through revealed preference measurement would concentrate on the worsening of congestion. The design would require, of course, the concurrent measurement of actual levels of service on facilities used or potentially usable by the sample in each location.

Two other potentially appealing aspects to the combination of revealed and stated preference measurements arise from the implementation of these two methods within the third approach, namely the establishment of longitudinal panels. Clearly, the only way in which changes in revealed preferences will be measured is through repeated measurement in a longitudinal survey design. The use of panels is a method that provides much greater accuracy in the measurement of those changes than can be obtained through the repetition of cross-sectional surveys over time.

The survey mechanism that is envisaged in this combined approach is one that might consist of;

- A survey of the demographics and other characteristics of each household and individual included in the sample;

- A stated preference survey of each individual covering a variety of changes in system performance that includes both increasing congestion and a scenario of capacity increase followed by an immediate improvement in level of service and a gradual subsequent degradation in service; and
- A multi-day activity diary to measure actual behavior over at least three days.

While it has been stated earlier that measurement of stated preference through a longitudinal panel seems to be relatively uninteresting, this changes when stated and revealed preferences are measured together and also if certain changes are made in the stated preference design. Combining revealed and stated preference questions in a longitudinal panel provides a richer base against which to determine consistency of revealed preferences with stated preferences and particularly enables review over time whether actual behavior changed at a point indicated by the stated preference data. Second, the panels can be asked stated preference questions on each repeat survey in which the options offered are largely at different levels on each occasion but with sufficient common ones to tie to the previous measurement. If stated preferences remain constant over time, as one would expect, this design would both substantiate the stability of stated preferences and provide, over a number of occasions, a far richer option set than would be possible in a single survey. If stated preferences were to be found to change over time, then this approach would reveal these changes and would provide additional insights on adaptation behaviors and value system changes that may explain why travel decisions are often harder than expected to influence through system improvements.

An advantage of the combined approach, undertaken in multiple locations but without an actual capacity-increasing project, is that the sphere of influence of a capacity-increasing project does not need to be defined in advance. Rather, the revealed and stated preference methods would assist in defining the sphere of influence by identifying the transportation corridors and the locations within the urban area that residents would choose or avoid, according to whether the questions relate to capacity increases or increasing congestion.

The focus of the above surveys is principally on residents of the areas. However, a very similar approach could be used for employers in which revealed and stated preference measurements could be undertaken with a panel of employers. Many of the same benefits of this combined approach would accrue for an employer survey as for a resident survey. The difference in this survey in administration is that no diary is probably of use, and the revealed and stated preference information may be obtained most expeditiously in a face-to-face interview. In addition, the household and individual demographics would be replaced by a set of characteristics describing the employer and its location.

Conclusions

Several conclusions can be drawn about experimental design for measuring the impacts of capacity increases in a congested travel corridor:

- A multi-year, longitudinal study is probably essential as the overall experimental strategy. Measurement over several years will almost certainly be necessary because of the time needed to reveal various behavior changes.
- A case study, comprising a location where a significant capacity increase is constructed, is probably neither necessary nor beneficial for the experimental design. The impacts of external events, the difficulties of identifying the impacted population and sampling from it, and the necessity for a parallel control location all make the case study a very difficult and possibly unrewarding option.
- The experimental design should use multiple locations with a common survey design and varying levels of existing congestion. Preferably the sampled individuals or households in each location should be drawn from similar household and individual demographic characteristics.

- Comprehensive measurement of performance of the transportation system in the vicinity of sampled households/individuals will be a key component of the study design.
- The study design should include surveys of both residents and employers in the study corridors. The survey of employers will likely use different techniques from the resident survey but should be designed to be consistent with the survey of residents.
- Conducting a series of focus groups should be considered a necessary pre-step before designing the survey and sample recruiting. The focus groups will be asked to respond to scenarios of increasing congestion and then relief of the congestion through the addition of new highway capacity.
- A combination of revealed preference and stated preference measurements seems likely to hold the greatest promise for both employer and resident surveys. The use of stated preference is particularly important given an experimental design in which there is no capacity-increasing project.
- The use of panels of individuals, households, and employers is likely to provide the most accurate tracking of change and provide the best basis for determining the validity of the stated preference measurement. Continuation in the panel of panel members who move away is also important to the study, to determine to what extent the new location offers a real improvement in transportation performance levels (if any).

References

1. David E. Boyce. Notes on the Methodology of Urban Transportation Impact Analysis. Highway Research Board Special Report No. 111. Transportation Research Board, Washington, D.C., 1970, pp. 41-44.
2. Midiael J. Demetsky and Frank D. Shepard. Measuring the Impact of a New Urban Highway on Community Traffic. Traffic Engineering. July 1972, pp. 42-45.
3. Christopher R. Fleet and Patrick DeCorla-Souza. VMT for Air Quality Purposes. Paper presented to the ASCE Specialty Conference on transportation Planning and Air Quality, Santa Barbara, CA, July 1991.
4. Greig Harvey and Elizabeth Deakin. Toward Improved Regional Transportation Modeling Practice. Paper presented to the National Association of Regional Governments Workshop on Transportation Planning for Air Quality, potentially Washington, D.C., November 1991.
5. Peter R. Stopher. The Impact of Capacity Increases on Congestion. Paper presented to the 7th REAAA Conference held in Singapore, June 1992.
6. R. Remak and S. Rosenbloom. Peak Period Traffic Congestion. Transportation Research Board Special Report No. 169. 1976, p. 62.

US Government Printing Office: 1994 -- 301-719/15753

NOTICE

This report is being distributed through the U.S. Department of Transportation's Technology Sharing Program.

DOT-T-94-12

DOT-T-94-12
n
n
TECHNOLOGY SHARING
A Program of the U.S. Department of Transportation

(EAT.html)

JUMP TO TOP